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Operation Heli-STAR - Helicopter Noise Levels Near Dekalb Peachtree Airport

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16. Abstract

Operation Heli-STAR (Helicopter Short-Haul Transportation and Aviation Research) was established and operated in Atlanta, Georgia, during the period of the 1996 Centennial Olympic Games. Heli-STAR had three major thrusts: 1) the establishment and operation of a helicopter-based cargo transportation system, 2) the management of low-altitude air traffic in the airspace of an urban area, and 3) the collection and analysis of research and development data associated with items 1 and 2. Heli-STAR was a cooperative industry/government program that included parcel package shippers and couriers in the Atlanta area, the helicopter industry, aviation electronics manufacturers, the Federal Aviation Administration (FAA), the National Aeronautics and Space Administration (NASA), and support contractors.

Several detailed reports have been produced as a result of Operation Heli-STAR. These include 4 reports on acoustic measurements and associated analyses, and reports on the Heli-STAR tracking data including the data processing and retrieval system, the Heli-STAR cargo simulation, and the community response system. In addition, NASA's Advanced General Aviation Transport Experiments (AGATE) program has produced a report describing the Atlanta Communications Experiment (ACE) which produced the avionics and ground equipment using automatic dependent surveillance-broadcast (ADS-B) technology. This latter report is restricted to organizations belonging to NASA's AGATE industry consortium. A complete list of these reports is shown on the following page.

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Volume 7 DOT/FAA/ND-97/15	Operation Heli-STAR - Cargo Simulation System; Ellen Bass, and Chasles Stancil; Georgia Tech Research Institute, Atlanta, Georgia, September 1997
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FOREWORD

This is Volume 2 of a 9-volume report documenting the activities and results of Operation Heli-STAR, the Atlanta Short-Haul Transportation System (ASTS). ASTS was a cooperative government/industry program that established a helicopter transportation system to support community of Atlanta during the 1996 Olympic games. Volumes 2 through 5 of this set of reports documents the noise studies that were performed during Operation Heli-STAR. The noise research was performed by Georgia Tech Research Institute (GTRI). GTRI also produced two additional reports documenting Operation Heli-STAR. Volume 6 describes the aircraft position data processing research, and Volume 7 documents a Cargo Simulation System that was used in support of Heli-STAR cargo operations. The research and development elements of Operation Heli-STAR were funded by the Federal Aviation Administration through Science Applications International Corporation (SAIC).

The GTRI manager of the overall ASTS program was Mr. C. Stancil. The Principal Investigator of the noise studies, reported in volumes 2 through 5, was Dr. K. K. Ahuja of GTRI. GTRI personnel responsible for making and analyzing day-to-day noise measurements were Dr. R. Funk and Mr. Jeff Hsu who were assisted by a team of 20 researchers. Ms. Marcie Benne, a graduate student from the School of Psychology lead the effort on the community survey reported in Volume 2. She was assisted by Ms. Mary Lynn Rivamonte, a student in the School of Aerospace Engineering. The authors are particularly grateful for Dr. Mike Heiges of GTRI for providing the helicopter altitudes and flight paths and to Mr. Stephen Williams, also of GTRI, for setting up the microphone locations for noise contour measurements.

The titles of the four volumes reporting noise research are:

Volume 2 - Helicopter Noise Levels Near Dekalb Peachtree Airport

Volume 3 - Helicopter Noise Annoyance Near Dekalb Peachtree Airport

Volume 4 - Helicopter Noise at Heliports

Volume 5 - Effects of Buildings on Helicopter Noise

The titles of the other two volumes authored by GTRI are:

Volume 6 - Aircraft Position Data

Volume 7 - Cargo Simulation System

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EXECUTIVE SUMMARY

Measurements of DNL were made in the vicinity of the Dekalb-Peachtree (PDK) helipad prior to the 1996 Olympic Games, during the Olympics and after the Olympics. Additionally, DNLs were monitored for a longer duration at three locations, two near the helipad, and one in a residential neighborhood. The effect of increased helicopter activity on DNL, due to the Olympic Games, was examined.

Sites monitored long-term near the helipad showed DNL levels between 65 and 70 dBA before and after the Olympic Games. During these periods, the DNL was lower during the weekends due to fewer flights by the media and traffic helicopters. During the Olympic Games, DNL levels rose substantially near the helipad due to the greater than threefold increase in the number of helicopter operations. Typical DNL levels ranged between 75 dBA and 78 dBA during this period. A neighborhood site, located northwest of the helipad, showed little effect on DNL due to increased operations. In this location DNL was found to be dominated by insect noise during the night hours.

DNL contours were constructed from short-term measurements at more than fifty locations around the PDK helipad made before, during, and after the Olympic Games. The highest DNL levels were seen near the helipad and near the MARTA rail station. Increases in DNL from before the games to during the games were largest near the helipad, with lesser increases in neighborhoods away from the helipad. DNL increases in neighborhoods in the period following the Olympics were noted due to increased insect noise during night hours.

SECTION 1

OBJECTIVE

The primary objective of this study was to monitor the impact of increased helicopter activity on the noise levels around a general aviation airport during the 1996 Olympic Games in Atlanta, Georgia. The specific objectives of the study were:

1. Measure the change in Day-Night Level (DNL) contours around the PDK helipad produced by the increased helicopter activity during the Olympic games.

2. Determine what effect helicopters had on the noise contours when operating together with general aviation, fixed-wing aircraft.

SECTION 2

BACKGROUND

2.1 Introduction to Noise Metrics

An introduction to the noise metrics used in this document is included here. The acoustical metrics described here are sound pressure level, A-weighted sound pressure level, equivalent continuous sound level, and day-night average sound level.

2.1.1 Sound pressure level

Sound is transmitted through the air by sound waves which are small oscillations in pressure. Impingement of these pressure oscillations on the ear produce the sound we hear. The sound waves can be characterized by two properties: the frequency of oscillation, measured in Hertz (Hz) and the sound pressure level measured in decibels (dB).

Sound pressure level is a ratio of the sound pressure of a source to a reference pressure. The reference pressure is 20 micropascals, the threshold of hearing. Decibels are a logarithmic scale of sound pressure level. The normal range of sound pressure levels encountered is from about 30 dB to 100 dB in everyday sounds.

It is important to stress the logarithmic nature of the sound pressure level. This prevents using simple addition when summing noise levels. For instance, if two noise sources each produce 100 dB individually, when operated together they don't produce 200 dB but 103 dB. Each doubling of the noise results in a 3 dB increase in the total. This also occurs when adding sources when one is much higher than the other. If an 80 dB source and a 100 dB source are operated together the resulting level would still be 100 dB. The louder source masks the quieter one. This holds true for sources with more than 12 dB difference.

2.1.2 A-weighted sound pressure level

An important characteristic of sound is its frequency. This is the rate at which sound pressure fluctuations are sensed by the ear. It is expressed in cycles per second or Hertz (Hz). The normal frequency range of hearing for most people extends from a low frequency of about 20 Hz to a high frequency between 10 and 15 kHz. But the sensitivity

to these frequencies is not uniform. People are most sensitive to frequencies in the range of normal conversation, typically from 1000 to 2000 Hz. People are much less sensitive to lower frequencies and somewhat less sensitive to higher frequencies. A filter, called an A-weighting filter, is used to weight different frequencies according to the sensitivity of the human ear at those frequencies. The relative response of this filter over the audible range is shown in Figure 2.1. This filter is applied to the linear output of a microphone system to more accurately reflect the level of the sound sensed by the human ear. This A-weighted sound level is referred to as dBA. For example, at 200 Hz, one needs to subtract 9 dB from the measured value to convert it to dBA. Normally, these additions and subtractions are done by an electronic filter network in the measuring instrument and one is presented with an overall dBA value. Because this filter generally matches the sensitivity of the human ear, sounds having higher A-weighted sound levels are judged to be louder than those with lower A-weighted sound levels, a relationship which might not otherwise be true. It is for this reason that A-weighted sound levels are normally used to evaluate environmental noise sources.

Because of the correlation with human hearing, the A-weighted sound pressure level has been adopted as the basic measure of environmental noise by the Environmental Protection Agency (EPA). It is measured in dBA.

2.1.3 Equivalent Continuous Sound Level (Leq)

The sound pressure level is an instantaneous measure of the noise level that varies with time. The Equivalent Continuous Sound Level, abbreviated Leq, is a measure of the exposure resulting from the accumulation of sound levels over a particular period of interest -- for example, a minute, an hour, or a full 24-hour day. The sound levels may be weighted and normally, for environmental measurements, A-weighting is used. Because the length of the period can be different depending on the time frame of interest, the applicable period should always be identified or clearly understood when discussing the metric. Such durations are here represented as $Leq_{(1\ min.)}$. The environmental mode used on the sound level meters employed in this study was able to record 1 minute or 1 second Leq's.

Conceptually, Leq may be thought of as a constant sound pressure level over the period of interest that contains as much sound energy as the actual time-varying sound level with its normal peaks and valleys. It is important to note, that, if heard, the two signals (the constant one and the time-varying one) would sound very different from each

other. Also, recalling the previous description of the addition of sound levels, be aware that the "average" sound level suggested by Leq is not an arithmetic mean, but a logarithmic, or "energy-averaged" sound level. Comparable to the addition of decibels, this means that higher A-weighted sound levels receive greater emphasis than lower values. For example, if the sound level is 50 dBA for 30 minutes, followed by 100 dBA for the next 30 minutes, then the Leq for the entire hour is calculated to be 97 dBA -- not the 75 dBA that we might expect. Thus, loud events clearly dominate any noise environment described by the metric.

In the present study, 1 minute Leq values are examined over a long period of time to quantify the effect of helicopter and aircraft activity.

2.1.4 Day-Night Average Sound Level (DNL)

The Day-Night Sound Level (DNL) represents a concept of noise average as it occurs over a 24-hour period. It is a metric developed by the EPA to account for the greater annoyance of noise when people are sleeping. It is much like a 24-hour Leq with the important exception being that the DNL treats nighttime noise differently than daytime noise. In determining DNL, it is assumed that the A-weighted levels occurring at night, between 2200 and 0700 the next morning, are 10 decibels louder than they really are. This 10-dB penalty is applied to account for greater sensitivity to nighttime noise, plus the fact that events at night are often more intrusive because nighttime ambient noise is less than that during the day.

Computed values of DNL are often depicted as noise contours reflecting lines of equal exposure around an airport (much as topographic maps indicate contours of equal elevation). The contours usually reflect long-term (annual average) operating conditions, taking into account the average flights per day, how often each runway is used throughout the year, and where over the surrounding communities the aircraft normally fly. Alternative time frames representing a single day or a typical seasonal day are also helpful in understanding shorter term aspects of a noise environment. In this study, DNL values were calculated from measurements over periods of one day or less in order to access the effect of large activity level changes.

Representative values of DNL in our environment range from a low of 40 to 45 decibels in extremely quiet, isolated locations, to highs of 80 or 85 decibels immediately adjacent to a busy truck route or off the end of a runway at an active Air Force base.

More typical values would be in the range of 50 or 55 decibels for a quiet residential community to 60 or 65 decibels in an urban residential neighborhood.

Why is DNL used to describe noise around airports? The U.S. Environmental Protection Agency identified the measure as the most appropriate means of evaluating airport noise based on the following considerations:

1. The measure should be applicable to the evaluation of pervasive long-term noise in various defined areas and under various conditions over long periods of time.

2. The measure should correlate well with known effects of the noise environment and on individuals and the public.

3. The measure should be simple, practical and accurate. In principal, it should be useful for planning as well as for enforcement or monitoring purposes.

4. The required measurement equipment, with standard characteristics, should be commercially available.

5. The measure should be closely related to existing methods currently in use.

6. The single measure of noise at a given location should be predictable, within an acceptable tolerance, from knowledge of the physical events producing the noise.

7. The measure should lend itself to small, simple monitors which can be left unattended in public areas for long periods of time.

Now most other public agencies dealing with noise exposure, including the Federal Aviation Administration (FAA), the Department of Defense, and the Department of Housing and Urban Development (HUD), also have adopted DNL in their guidelines and regulations. Generally, the regulations require that homes and schools be outside the 65 DNL contour, and light industrial operations occur in areas with up to 70 DNL.

SECTION 3

TEST SETUP AND METHODOLOGY

3.1 Test Location

3.1.1 Dekalb-Peachtree Airport

All noise monitoring for this portion of the study was done in the vicinity of the Dekalb-Peachtree Airport (PDK) northeast of Atlanta. This location was chosen because of mixed fixed-wing and rotary-wing operations and because of the greatly increased helicopter traffic expected during the Olympic period. Prior to the Olympic games, PDK supported some helicopter activity in the form of news and traffic helicopters. During the Olympic games, PDK was the staging area for all the broadcast media helicopters, a fleet of helicopters for use by games officials, and the package transport helicopters used in the FAA Heli-STAR demonstration project. There was also an increase in traffic of larger fixed-wing aircraft due to the games. Traffic of smaller, general-aviation aircraft reduced during the games due to more stringent regulations for flight slot reservations. PDK was also the staging site for media blimp activity during the games.

Figure 3.1 shows the location of the airport relative to the major interstates in the Atlanta metro area and the "Olympic Ring", the area encompassing the Olympic Village and the downtown venues. Its proximity to the venues and availability of support equipment and parking area made it a popular location for helicopter activities. A map of the airport and the surrounding area is presented in Figure 3.2 showing the prescribed flight path for helicopter traffic and the noise measurement locations. The helipad is located at the northwest corner of the airport at the end of runway 16/34. This runway was closed during the Olympic games, all fixed-wing traffic using runways 2R/20L and 2L/20R. The fixed-wing flight path in and out of these runways is also shown in the figure. Landing and takeoff directions were dictated by the wind conditions, but the majority of the landings and take-offs occurred to the southwest. The helipad was under construction during the period prior to the Olympics. During this time, helicopter traffic was departing to the east of the runway 16 threshold. When the helipad was opened, approximately three weeks prior to the Olympics, the departure and arrival point for helicopter traffic moved approximately 500 ft to the northwest.

The area to the west of the helipad is a residential neighborhood. To the north is a MARTA light rail station and light industrial/commercial areas up to Peachtree Industrial Blvd. North of Peachtree Industrial Blvd., there are residential neighborhoods and a public park. The prescribed approach and departure path for helicopter operations was from the helipad to the northwest over the MARTA station and then turning to the southwest to follow the Peachtree Industrial Blvd./MARTA rail alignment to minimize noise exposure to the residential areas.

3.1.2 Noise Measurement Locations

Over fifty noise measurement locations were selected in the area around the helipad. Since the project concentration was on helicopter noise, the measurement locations were concentrated around the northwest corner of the airport where the majority of helicopter activities occur. The measurement locations were selected to be in publicly accessible areas, normally public easements near roads, open fields, public parks, and lightly utilized parking lots. The locations are denoted on Figure 3.2 by circled crosses and numbers. Table 3.1 gives a description of the location and its approximate distance in feet from the helipad.

Location	Description	Distance from Helipad(ft)
1	Flightway Dr, manhole across from 2003 Flightway Dr.	748
2	Flightway Dr,across from 2007 Flightway Dr, marker at edge of Kudzu	966
3	Flightway Dr, NW corner of parking lot across from Honeybaked Ham	1404
4	Corsair Dr,yard by 3254 Corsair hangar, 8' from fence	1093
5	Corsair Dr,yard by 3234 Corsair,8' from fence between building and light pole	1089
6	Corsair Dr,yard between hangars and AirBP at lightpole	1121
7	Flightway Dr, rock across from helipad fuel tank	558
8	Flightway Dr, large rock outcropping across from helipad	550
9	Flightway Dr, behind large boulder, west of loc 8	544
10	NW corner of Hardee and Wingate, 20' back from roads	512
11	Hardee Ave, next to entrance gate for 3381 Hardee	427
12	E corner of Hardee and Fourth, next to 3345 Hardee	938
13	NE corner of Chamblee library parking lot	979
14	manhole cover in front of 1962 Wingate	688
15	SE corner of Bozeman&Clairwood Terr, yard of 3223 Clairwood Terr	1200
16	SW corner of Clairwood&Lawson (gravel driveway)	1429
17	drain next to 1889 Ham Dr.	1728
18	dead end on Dyer Cir	1749

20	manhole between 1888&1898 Dyer Cir	1838
21	field at Hickory and Clairmont, backside away from Clairmont along Hickory	1835
22	corner of Hickory and Jefferson, next to fire hydrant	2039
23	corner of Hickory and Canfield,back on Canfield near telephone pole	2358
24	corner of Knox&Canfield near stop sign	2524
25	easement in front of 3043 Jefferson	2593
26	corner of Knox&Skyland near yield sign	2787
27	corner of Park&Skyland, corner with 3039 Park Ln	3132
28	N corner of Hickory and Park	2743
29	bushes next to 1825 Hickory	2812
30	6th&Clairmont in field across from entrance gate	1857
31	Watkins and Interactive College of Technology corner away from New P'tree	1384
32	Interactive CofT parking lot at Hood Ave	1833
33	Chinese Comm Center parking lot, at back wooden fence	2676
34	Pierce Dr across from Eckhart electric, next to easement post	2957
36	Cemetary off Pierce Dr, end of drive	3370
38	back corner of parking lot at Peachtree Rd and Malone Dr.	1877
39	International Farmers Market, 3rd light pole from building along back fence	2224
40	field at Catalina&Chamblee-Tucker, near small pine tree	2845
41	Ann Dr, end near runway, at the fire hydrant	3013
42	Ann Dr, intersection with Munday, away from runway	3163
43	yard across from 3504 Sexton Woods Dr, near schoolwalking sign	3961
44	schoolyard at corner of Sandlewood and Sexton Woods Dr.	4773
45	corner of Hamlin and Keswick next to 3597 Keswick	5094
46	Keswick Park, rock outcropping at EB Malone Ballfield	4329
47	Keswick Park, center of grass field next to road to EB Malone field	4113
48	Keswick Dr, far side of senior ballfield (third baseline)	3172
49	Keswick Dr, center of plateau between ballfield and road	3282
50	Keswick Dr, farside of little league field	3482
51	Keswick Dr, field behind senior ballfield, near woods edge	3282
52	helipad, inside fence along Flightway	318
53	helipad, inside fence along Hardee	275
54	MARTA parking lot 8 , near light pole at New P'tree entrance	812
55	MARTA parking lot 2 along Peachtree Rd, back corner near Clairmont overpass	1400
56	SW corner of Jefferson&Canfield	2432
57	Cemetary at New P'tree and 8th, steel marker just inside gate	4138
58	Church at New P'tree and 8th, south side in yard even with side door	3985
59	Backyard of 3402 Keswick Dr., outside and to the left of chain link fence at rear of yard	3770

Table 3.1: List of measurement locations around the PDK helipad.

3.2 Test Equipment

3.2.1 Equipment overview

The outdoor acoustic measurements envisioned for this program dictated a portable, battery-powered, weather-resistant unit. Additionally, the ability to log Leq values for computation of DNL was required. This was accomplished with portable sound level monitoring setups. Each setup consisted of a sound level meter and battery pack in a waterproof case and a tripod with a wind screen and rain protection for the microphone. A digital audio tape (DAT) recorder was supplied to enable recording of raw data.

Each noise measurement setup consisted of the following components:

- CEL Type 1 Sound Level Analyzer Model 573 or 593
- CEL-527 Preamplifier
- CEL-250 Type 1, 1/2" Electret microphone
- Sony TCD-D8 DAT tape recorder
- CEL-284/2 Type 1 acoustic calibrator
- 5 meter microphone extension cable
- CEL-594 wind and rain protection system for microphone
- tripod
- rechargeable battery
- weather-resistant case

Three types of meters were used: CEL-573.A1, CEL-573.C1, and CEL-593.C1. All meters had A and C weighting filters. The CEL-573.C1 and CEL-593.C1 also included octave and third octave filters. Twenty-two of these setups were used in this study. Figure 3.3 shows a meter setup. The microphone and preamplifier are shown mounted on a tripod and protected by wind and rain gear.

3.2.2 Operation and parameters measured.

All SLM's had the ability to log Leq values over 1 minute or 1 second time periods, two frequency weightings could be selected. The meters also contained internal clocks for time stamping and a timer to turn the meter on and off at specified start and stop times. For all tests at PDK the SLM's were setup to measure 1 minute Leq with A-

weighting and linear weighting. The logged Leq values were tagged with a time of day based on a clock internal to the SLM. The SLM contained enough memory to log approximately six days of 1 minute Leq values, although the batteries would last less than two days.

Operationally, the meters were run as follows:

1. All meter clocks were synchronized.
2. The equipment was setup at the assigned location. The microphone was mounted five feet from the ground and the SLM case was moved away from the microphone location to minimize interference.
3. A calibrator was used to calibrate the SLM.
4. The SLM was set to log 1 minute Leq values, both A-weighted and linear-weighted.
5. The SLM start-stop timer was set for the required acquisition time.
6. The SLM was checked periodically during the acquisition to ensure correct operation of the equipment.
7. Activity around the test location was recorded on log sheets by the test personnel, noting any abnormal occurrences.
8. The calibration of the equipment was checked at the conclusion of the acquisition and any deviation noted on the log sheet.

3.3 Testing Methodology

3.3.1 Data acquisition duration

The majority of the test locations used were unsecured and required monitoring of the test equipment. A number of Georgia Tech researchers were employed for this purpose. There were also a fixed number of monitoring units available. These factors limited the amount of time data could be acquired at any given location.

However, three locations were secure enough that equipment was left for extended periods without monitoring. These locations were inside the fence line at PDK to the north and west of the helipad, and in the backyard of a home located at 3402 Keswick Dr. in a neighborhood north of Peachtree Industrial Blvd. Data were acquired over 24 hours in these locations. Data were gathered at the helipad locations starting on 20 May 1996. Initial data gathering at the Keswick Dr. location was begun on 12 July 1996. (The Olympic Games started on July 19.) The data from the pad locations were used to verify the data reduction methodology used to determine DNL values from data sets of less than 24 hours as described in Section 3.4 Data Reduction.

At other locations, data were acquired in shifts over a period of days. The 24 hour data indicated that levels were fairly consistent during weekdays and dropped slightly over the weekends. Therefore, data from different shifts on various weekdays were used in the calculation of DNL values.

3.3.2 Comparison of contours with varying activity levels

The objective of measuring changes in DNL contours due to changes in activity levels led to the approach of measuring the levels prior to the Olympics, during the Olympics, and after the Olympics. The pre-Olympic testing was done between 10 June 1996 and 27 June 1996. Data were acquired in the morning, afternoon, and evening shifts over this period covering hours of the day from approximately 0600 to 2300. During the Olympics, the window of opportunity was much smaller dictating a double shift acquisition process during the first week of the games, from 22 July 1996 to 26 July 1996. In this case, a morning shift started slightly after 0600 and was relieved by a second shift between 1400 and 1500 continuing until 2300. In this case all data for a given location was acquired on the same day. The final set of testing was done between 3 September 1996 and 12 September 1996 at a slightly reduced set of locations to determine if DNL values had returned to pre-Olympic levels. In this case 0600 to 1400 and 1430 to 2300 shifts were used.

During the pre-Olympic period, the total number of helicopter and fixed-wing operations noticed by the data acquisition operators during the monitoring of the equipment were counted. During the Olympics and the post-Olympic period more detailed records of the time of each flight were made by the data acquisition crew. Additionally, at least one of the personnel was stationed at a location in view of the helipad during all of the monitoring periods in an effort to get an accurate count of all helicopter operations during these periods.

3.4 Data Reduction Methodology

3.4.1 Description of the method

As presented previously, the day-night average sound level (DNL) is calculated based upon the Leq for the day-time period (0700-2200) and the Leq for the night-time period (2200-0700). As described in the previous section, in the present study, the acoustic measurement for both A-weighting and linear weighting Leq (1 min.) were

logged at each measurement location for the duration of 0600 to 2300 in pre-Olympic, during-Olympic and post-Olympic periods. The Leq for the day-time period can be easily obtained by finding the logarithmic average of all the Leq (1 min) values acquired during the day-time period at each measurement location since the entire day-time period was included in our measurement duration.

Similarly, it's desirable to obtain the night-time Leq by applying logarithmic averaging to all the Leq values acquired during the night-time period at each measurement location. However, to optimize the usage of personnel and the available funding, the night-time Leq measurement was acquired at its entirety only at selected locations. At most measurement locations, since the occurrence of the noise events lessened drastically between 2300 and 0600, during the night-time period, the Leq (1 min) values were measured from 2200 to 2300 and from 0600 to 0700 and the Leq values for the remaining portion of the night-time period were derived from the data obtained during these periods. The remaining night-time Leq was assumed to be a combination of the measured night-time Leq and the minimum of the levels seen between 2200 and 2300, and between 0600 and 0700. In the case of locations near the helipad, DNL was dominated by daytime noise events and sensitivity of the DNL to the selection of a night-time level was small. This procedure was important in neighborhood areas where insect noise was dominant and was a major contributor to the overall DNL. By combining the measured portion and the derived portion of night-time Leq, a night time Leq can be obtained with close approximation to be used for the calculation of the DNL level.

3.4.2 Verification of the method

The data reduction methodology used to determine DNL values from data sets of less than 24 hours was verified with data acquired at locations where the sound level meters were left for extended periods as described previously. A typical 24 hour Leq trace acquired at the Flightway Dr. location is presented in Figure 3.4. Since the data set includes the entire 24 hour period, the day-time and the night-time Leq can be obtained through logarithmic averaging of the data and the DNL level for that 24 hour period can then be calculated to be 69.35. Simulating the data set of less than 24 hours, the data from 2300 to 0600 were replaced by Leq values derived from our data reduction methodology and the resulting DNL value was calculated to be 69.34. Several other sets of 24 hour data were also used to verify the data reduction methodology that is summarized in Table 3.2. As presented in this table, the differences between the estimated DNL and the actual DNL levels were within acceptable ranges.

Location	Date	DNL (dBA)	estimated DNL (dBA)	Delta (dBA)
Flightway Dr.	20-May-96	71.87	72.43	0.56
Flightway Dr.	29-May-96	68.84	68.90	0.06
Flightway Dr.	31-May-96	63.47	62.27	-1.21
Flightway Dr.	6-Jun-96	65.39	65.34	-0.05
Flightway Dr.	12-Jul-96	69.35	69.34	-0.01
Keswick Dr.	26-Jul-96	62.68	61.35	-1.33
Flightway Dr.	4-Sep-96	67.76	67.63	-0.14

Table 3.2: Verification of DNL reduction methodology on 24 hour data sets.

SECTION 4

RESULTS AND DISCUSSION

4.1 Variation at sites monitored long-term

4.1.1 Sites monitored

Long term monitoring of sites near the helipad at PDK began soon after receipt of the SLM equipment in late May 1996. Initial monitoring was at locations 52 and 53, inside the perimeter fence to the north and west of the helipad, along Flightway Dr. and Hardee Ave, respectively. Data from this initial monitoring was used to develop the data reduction methods for data comprising less than 24 hours as described in Section 3.4. Twenty-four hour monitoring at location 59, the backyard of 3402 Keswick Dr., began after contact with the residents was made through a noise survey (reference) starting 12 July 1996. This location was to the northwest of the helipad and north of the designated helicopter approach and departure route, although some helicopters were noted in the area during the data acquisition activities. The rechargeable batteries powering the equipment normally lasted two to three days. Variability in the state of charge of the batteries sometimes led to premature expiration, causing some gaps in the record where no data were acquired.

4.1.2 Daily variation of DNL

A plot of the variation of DNL values calculated from Leq values measured at the three above-described locations is shown in Figure 4.1. The labeled dates on the axis are Sundays, spaced three weeks apart. The Olympic period is marked on the figure from the opening ceremonies on 19 July 1996 to the closing ceremonies on 5 August 1996. The pre-Olympic values of DNL range from 62 to 71 dBA. This variation in noise amplitude tended to follow the day of the week, weekdays were higher than weekends. Both the Flightway Dr. location and the Hardee Ave location exhibited similar trends. The Hardee location was slightly closer to the helipad, but the Flightway location was more directly in line with the flight path and so exhibited higher levels.

A quick rise in DNL began prior to the games as additional helicopters for the media, ACOG, and the Heli-STAR program arrived and began their preliminary operations. This rise in noise began on 15 July 1996, the Monday before the opening ceremonies. As a result of this increased level of helicopter activity, the DNL values

calculated rose to levels between 75 and 78 dBA. There is much less scatter in this data as compared to the pre-Olympic period and no appreciable drop in level during the weekends. Just prior to the beginning of the Olympics, noise monitoring began at the Keswick location finding a DNL level of 63.7 dBA on 12 July 1996. During the games, levels at this location remained in the 63 to 64 dBA range.

During the second week of the Olympics, the DNL levels fell. The road traffic situation was not as bad as predicted resulting in a reduction in flights in the second week. In the weeks following the games, the DNL levels fell into pre-Olympic ranges at the helipad monitoring locations at Flightway Dr. and Hardee Ave. The same pattern of higher weekday levels and lower weekend levels was again apparent. The neighborhood location at 3402 Keswick Dr., however, showed increasing values of DNL into September. This was found to be due to insect noise during the nighttime hours. This noise had first been seen in the data from the Keswick Dr. location prior to the Olympics, and it increased in the following months. The effect of moving the helipad location to the northwest prior to the Olympics seems to have had very little effect on the measured DNL near the helipad.

4.1.3 Examination of Leq variation

Pre-Olympics

Five points are labeled on Figure 4.1, which will be examined in more detail here. Figures 4.2(a) and (b) show the 24 hour Leq traces used to calculate DNL for 12 July 1996 at the Flightway Dr. location and the Keswick location, respectively. These correspond to points F1 and K1 on Figure 4.1. The nighttime hours during which the 10 dB penalty is added are indicated on the time axis. The data is plotted as measured and the 10 dB nighttime penalty was later added in the computation of DNL. Figure 4.2(a) is illustrative of the type of trace seen near the helipad during the pre-Olympic period. Activity caused short-term increases in Leq, producing one minute Leq values as high as 88 dBA. The ambient levels varied between 55 and 60 dBA during the daytime hours. At night, the levels dropped below 50 dBA, sometimes under-ranging the meter at 40 dBA. The computed DNL for this day was 69.4, the level being dominated by the peaks due to flight activity during the day. The plot from Keswick Dr. shows a quite different trend. The plot still exhibits peaks during the daytime hours due to activity, but they are rarely above 65 dBA due to the distance from airport activity. Ambient levels here were much lower than near the helipad, sometimes under-ranging the meter during the day.

However, at night the recorded Leq increased to between 56 and 58 dBA. This almost constant droning was attributed to insects, probably katydids and tree crickets. When adding the 10 dB nighttime penalty, these levels are higher than the daytime peak levels. This effect was totally unanticipated based on the data previously gathered at locations near the helipad. In this case the DNL is dominated by the nighttime noise. DNL for this case was calculated to be 63.7.

In order to further investigate the effect of insect noise on the DNL computation, some data was gathered at a secluded mountain location near Franklin, Tennessee. At this location there was no noise due to aircraft or other transportation sources. A plot of the data gathered starting 10 August 1996 is shown in Figure 4.3. The DNL computed from this data was 59.6, while the average daytime level was around 45 dBA. Again, in this case, the constant droning of the insects at night, having levels between 55 and 60 dBA, dominates the DNL. These levels are lower than would be experienced with a helicopter flyover, although a helicopter flight would be a temporally short event, while the insects provide a constant drone.

<u>During Olympics</u>

Plots of Leq measured during the Olympics period are presented in Figure 4.4. Figures 4.4 (a), (b), and (c) are plots of Leq at the Flightway Dr., Hardee Ave and Keswick Dr. locations, respectively. These were the data used to compute the points labeled F2, H2, and K2 on Figure 4.1. Plot 4.4(a) shows peak Leq values slightly higher than the corresponding pre-Olympic plot at the same location (Fig. 4.2(a)), but there are many more peaks due to the greater activity level. Again, the nighttime hours exhibit Leq's below 50 dBA, although activity lasts longer into the evening and begins earlier in the morning. The computed DNL of 75.7 is dominated by the daytime activity level. This is an increase of 6.3 dBA from the pre-Olympic case. The plot in Figure 4.4(c) shows measurements from the Hardee Ave. location. It shows the same trends as Figure 4.4(a) with slightly lower peak values contributing to a lower DNL of 74.0. Figure 4.4(b) shows the Leq variation from the Keswick Dr. location. The peak Leq's measured during the day approach 70 dBA, higher than that for the pre-Olympic period. The same 56-58 dBA insect noise is observed during the nighttime hours and it again dominates the DNL. The computed DNL for this data was 62.7 which was actually 1 dB lower than that during the pre-Olympic period.

<u>Post-Olympics</u>

Measured Leq variations at the three locations during the post-Olympic period are shown in Figure 4.5. Figure 4.5(a) corresponds to point F3 on Figure 4.1 and is from the Flightway Dr. location. Figure 4.5(b) is the data from the Hardee Ave location and its DNL is labeled H3 on Figure 4.1. Both these plots follow the same trend, having peak Leq values during the daytime hours and lower values during the nighttime hours. Both have a peak due to some activity at approximately 0100, otherwise the nighttime levels are mostly below 50 dBA for the Flightway Dr. location and approximately 53 dBA for the Hardee Ave location. The computed DNL for the Flightway Dr. location is 67.8, which is 1.6 dB lower than that shown in Figure 4.2(a). The Hardee Ave location posted a DNL of 66.8, again slightly lower than at Flightway. The DNL values near the helipad returned to pre-Olympic levels.

Figure 4.5(c) is a plot of data from the Keswick Dr. location. The daytime peaks are lower than those seen during the Olympics, but the insects now are even louder. Levels begin at 58 dBA in the evening and increase throughout the night to a high of 65 dBA by 0600. These levels were higher than previously measured during the pre-Olympic or Olympic periods. This contributed to a DNL of 69.4, which is 5.7 dB higher than the pre-Olympic measurement shown in Figure 4.2(b). This trend continued through the post-Olympic period consistently having DNL readings in the 67-69 range. These levels exceed the 65 DNL requirement for residential areas, but the high levels are due to the insect noise during the nighttime hours. The constant drone of insects create the high DNL measured in this location, although this level is much less than the peak levels that would be experienced from a small number of aircraft flights if they were to cause the same DNL without the insects. In this case the DNL metric is somewhat misleading, in that people don't find the constant hum of insects as annoying as a small number of peak events, such as aircraft flights.

4.2 DNL Contours

4.2.1 Pre-Olympic contour

Monitored recording of one minute Leq values was carried out over the period of 10 June 1996 to 27 June 1996. Measurements were made during the weekdays. Each location was monitored for at least 15 hours between the hours of 0600 and 2300. The data were reduced as described in Section 3.4. The resulting DNL contours are presented in Figure 4.6. A small area of values over 70 dBA exists around the area of the Chamblee MARTA station to the northwest of the helipad. This is due to a combination of the

helicopter activity and the MARTA train activity. The 65 DNL contour extends from the helipad to the northwest encompassing an area from the Clairmont Rd.-New Peachtree Rd. intersection into the industrial area between Clairmont Rd. and Chamblee-Tucker Rd. An additional area of 65 DNL or higher located in the eastern part of the measurement area, near Catalina Dr., was due to fixed-wing traffic on the main runway. The majority of the neighborhood to the west of Clairmont Rd. and the neighborhoods in the Keswick Dr. and Sexton Woods Dr. area had DNL values between 55 and 60.

4.2.2 Olympic period contour

The noise measurements were repeated during the Olympic time period from 22 July 1996 to 26 July 1996. These measurements were done in two shifts during these five days. The meters were set to log from the time they were setup between 0600 and 0630 until 2300. The personnel changed shifts at approximately 1430. During the acquisition, the times of helicopter, aircraft, and ground transportation events were recorded at each location. Due to parking constraints during the games, some locations became inaccessible and thus were not monitored during this period.

The DNL contours resulting from this period are shown in Figure 4.7. The extent of the area contained by the 70 DNL contour increased. The 70 DNL contour extended to contain the helipad area and still contained the Chamblee MARTA station. The 65 DNL contour extended to contain the majority of the industrial area between New Peachtree Rd and Peachtree Industrial Blvd. The neighborhoods to the west of Clairmont and along Keswick Dr. and Sexton Woods Dr. had DNL values between 60 and 65.

4.2.3 Post-Olympic contour

During the period from 3 September 1996 to 12 September 1996, a final set of measurements was made. In this case, a morning shift was used the first week and an evening shift used the second week. Approximately 15-16 hours of Leq data were acquired at each location spanning the hours of 0600 to 2300. Again, the data monitoring personnel recorded the activities by time in the area of their equipment.

The DNL contours computed for this case are shown in Figure 4.8. The 70 DNL contour included the Chamblee MARTA station and was approximately the same size as during the pre-Olympic measurement period. The 65 DNL contour was larger in this case than in the pre-Olympic case. The neighborhoods fell in the area between the 65 DNL and the 60 DNL contour. The larger values in this case as compared to the pre-

Olympic case are partially attributable to the insect noise increase seen in the long-term monitored Keswick Dr. data.

The DNL values for each of each of the locations are listed in Table 4.1.

Location	DNL		
	pre-Olympic	Olympic	post-Olympic
1	64.3	66.9	66.9
2	60.8	65.3	63.9
3	59.5	59.8	62.3
4	58.8	66.5	60.3
5	58.6	62.3	61.8
6	57.5	65.5	61.2
7	69	72.5	66.7
8	65.3	71	61.7
9	61.6	72.2	
10	62.8	70.1	64.8
11	62.6	62.4	64.1
12	62.1	72	77.6
13	57.8	62.1	63.7
14	61.1	64.1	63.9
15	58.9	62.7	69.8
16	57.1	60.9	65.5
17	55.9	62.1	62.3
18	56.4	60.5	62.4
20	56.2	62.9	66.8
21	58.8	63.7	64
22	57.8	63.6	64.5
23	55.1	62.3	63.9
24	56.9	64	
25	59	66.1	67.2
26	58.4	62.1	61.6
27		64.1	61.2
28	57.5	63.4	65.5
29	59.1	62.9	65.3
30	61.7	61.6	
31	59.8	64.6	62.3
32	63.9	64.8	
33	63.7	65	
34	62.9		
36	58.7	64.6	
38	60.1	71.3	
39	62.8	62.6	
40	70.1	65.9	
41	66.7	66.5	
42	64.8	62.4	
43	58.1	59.9	65.5
44	54.6	56.9	61.1

45	56.9	58.1	
46	59.6	57.7	51.4
47	54	59.5	61.3
48	57.7	59.5	
49	57.6	59.7	59.3
50	57.5	61.1	
51	57.5	59.5	63.9
54	69.8		
55	72.3	71.6	71.2
56	60	62.8	64.3
57	64.4	64.2	61
58	60.2	60.4	60.6

Table 4.1: Computed DNL values for each measurement location.

4.2.4 Changes in DNL

Figure 4.9 shows the change in DNL from the pre-Olympic period to the period during the Olympics. The largest increases were seen in the area near the helipad. Areas to the west and north of the helipad had increases in DNL of between 3 and 6. The neighborhoods of Keswick Dr. and Sexton Woods Dr. showed increases between 0 and 3, with some neighborhood areas near Clairmont road exhibiting slightly higher increases. The increasing level of activity mainly effected DNL near the helipad. The effect was less pronounced in areas away from the helipad.

The change in DNL between the pre-Olympic and post-Olympic measurements is plotted in Figure 4.10. In this case, the changes near the helipad are small, showing that DNL in this area had returned to pre-Olympic levels. Some of the variation in this area can be explained by the day-to-day variation noted in noise at the long-term monitored sites. In the neighborhoods, changes in DNL were typically higher, this in large part due to the increasing insect noise in the post-Olympic period.

4.3 Activity Levels

The level of activity of various ground and air transportation sources has a primary effect on DNL levels. The level of activity of propeller and jet aircraft, helicopters, MARTA trains, trucks, and buses were monitored in detail during data acquisition. Figure 4.11 shows a plot of helicopter activity counted during the post-Olympic period which is typical of the normal, year-round activity levels. <u>Both the size and the shading of the points are indicative of the number of helicopters seen during the</u>

16 hour data acquisition period. Figure 4.12 shows the helicopter activity for the Olympics period. The largest number of operations were noted near the helipad, from locations with an unimpeded view of the pad. In neighborhood areas, views were obstructed and thus observation levels were lower. Figures 4.13 (a), (b) and (c) show composite plots of activity levels of helicopters, jets, and MARTA trains superimposed on the Olympic 65 DNL contour. Helicopter activity was noted mostly near the helipad. Jet aircraft were noted mostly on the eastern side of the measurement area, nearest the runway approach. They were also noticed a large number of the other measurement locations to some extent, indicating that noise from these operations had an effect on almost all locations. The MARTA activity was mostly seen at locations near the station and the rail line, contributing to the overall DNL in those areas. Digital audio tape (DAT) recordings of these various activities were made during data acquisition. It is hoped that these in concert with the recorded activity levels may be used to determine the relative contributions of each to the measured DNL.

The variation in helicopter activity at the PDK helipad over time is shown in Figures 4.14 and 4.15 for the Olympic period and post Olympic period, respectively. This information was recorded by the data monitor at location 7, which was directly across from the helipad fuel tank. Figure 4.14, during the Olympics, shows much higher activity levels throughout the day than the post-Olympic plot, Figure 4.15. During the Olympics, a total of 292 helicopter operations were recorded between 0615 and 2300, for an average activity level of 17.4 flights per hour. The DNL for that day was 77.5. The data for Figure 4.15 was gathered over two days from 0615 to 1400 and 1530 to 2300. During these times a total of 77 operations were noted, resulting in an average activity level of slightly more than 5 flights per hour. In this case the DNL was 66.7, a three-fold increase in activity resulted in a 10.8% increase in DNL at this location. The peak activity levels were seen to occur in the morning and then again around 1800. These correspond with the news and traffic helicopter activities during the morning and evening rush hours. During the normal operations at PDK, mostly Bell 206B and 206L, and Robinson R22 helicopters are used. During the Olympics, a wider variety of helicopter types were seen including B0105 and Bell 412 helicopters used in the Heli-STAR program.

SECTION 5

CONCLUSIONS

This study led to some conclusions about helicopter noise and its relationship to DNL and other environmental effects on DNL.

1. Increasing helicopter activity led to higher measured DNL.

   Comparison of DNL values measured prior to the Olympics and during the Olympics showed the greatest increases near the helipad, while values in neighborhoods near the airport showed much smaller increases. The three sites monitored long-term also exhibited this pattern. The two sites near the helipad showed marked increases in the DNL during the high activity of the Olympics, while a neighborhood site, not directly in the helicopter flight path, showed very little increase during the Olympics.

2. Other forms of transportation influenced the measured DNL.

   The Chamblee MARTA station, located north of the helipad, had increases in both rail and ground transportation activity during the Olympics contributing to the DNL increases around its location. The eastern portion of the measurement region bordered on the approach for runway 20 and the DNL in this region was dominated by fixed-wing aircraft noise.

3. Insect noise can have a strong influence on DNL in quiet areas.

   In quiet neighborhoods, it was discovered that a constant insect noise throughout the night was contributing to a substantial increase in DNL levels. The long-term monitored Keswick Dr. location showed this in having increasing DNL values after the Olympics due to increasing insect noise.

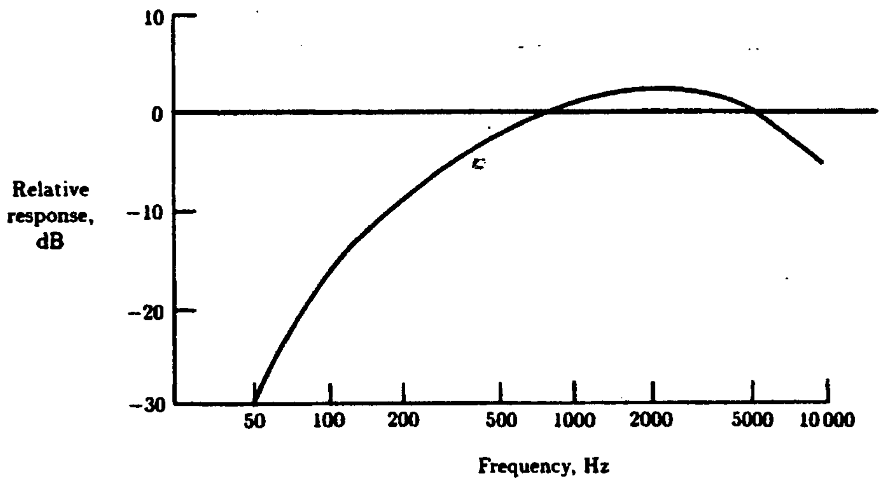


Figure 2.1 Relative response of the A-weighting filter.

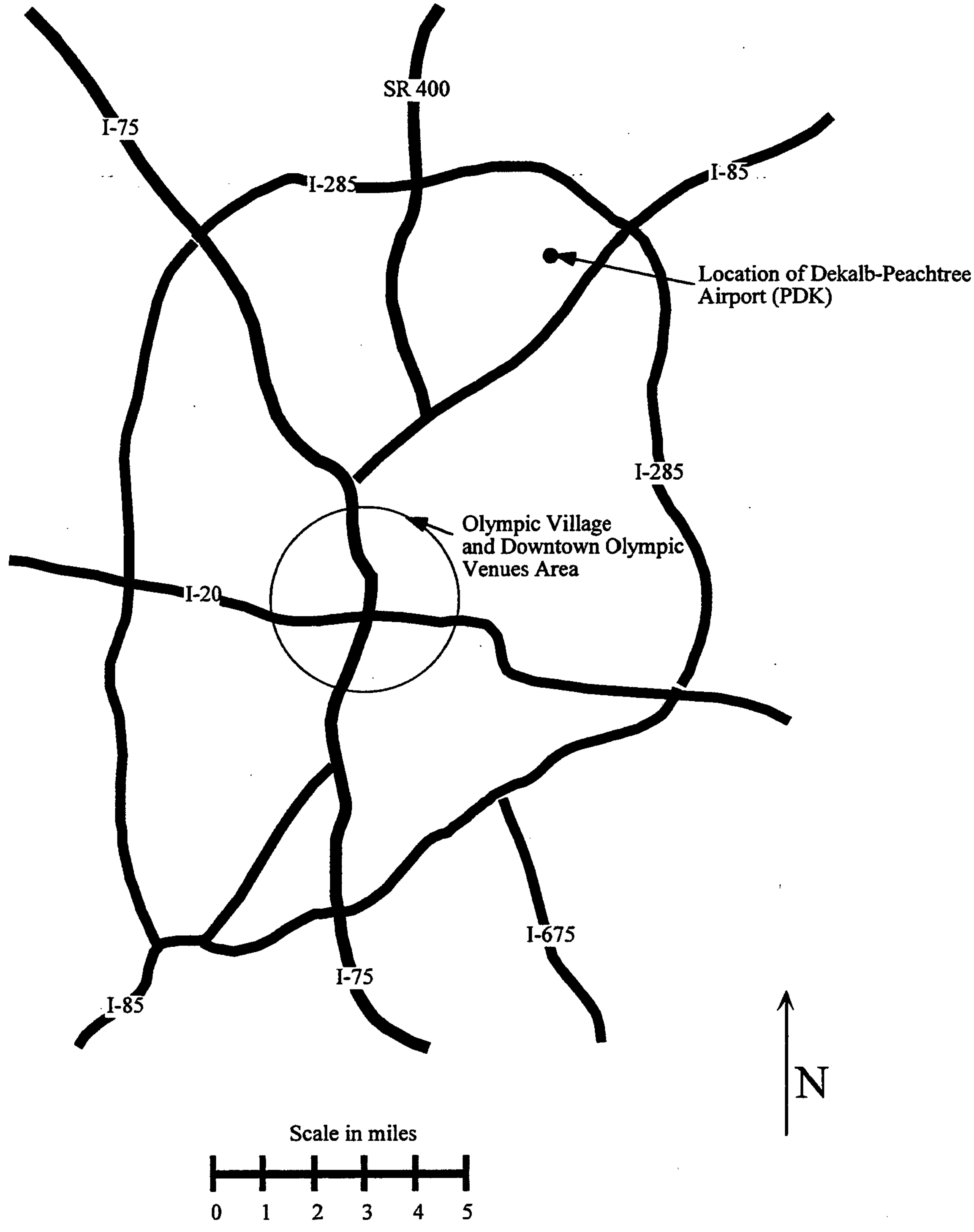


Figure 3.1 Atlanta area map showing the location of Dekalb-Peachtree airport.

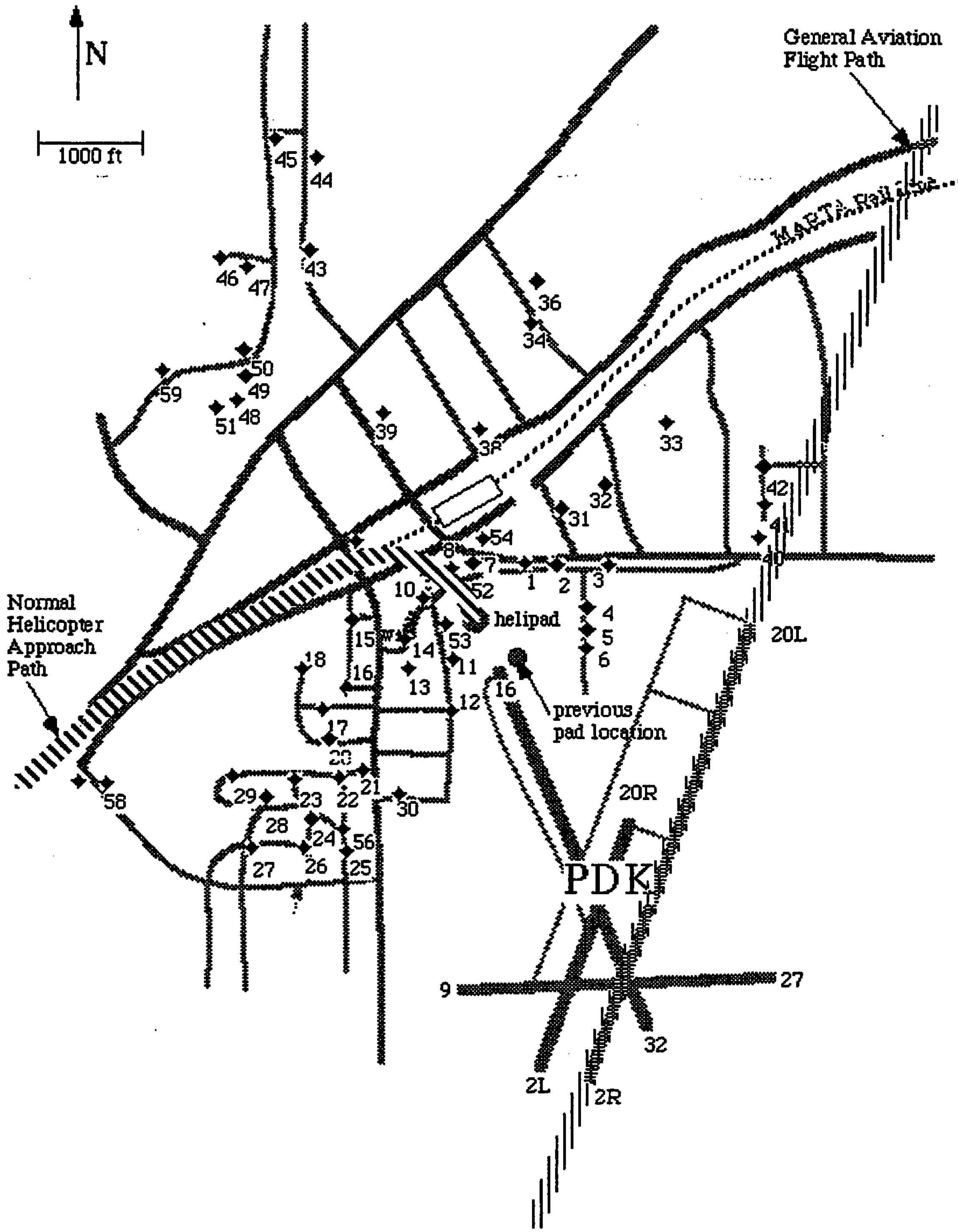


Figure 3.2 Map of the area in the vicinity of the PDK helipad.

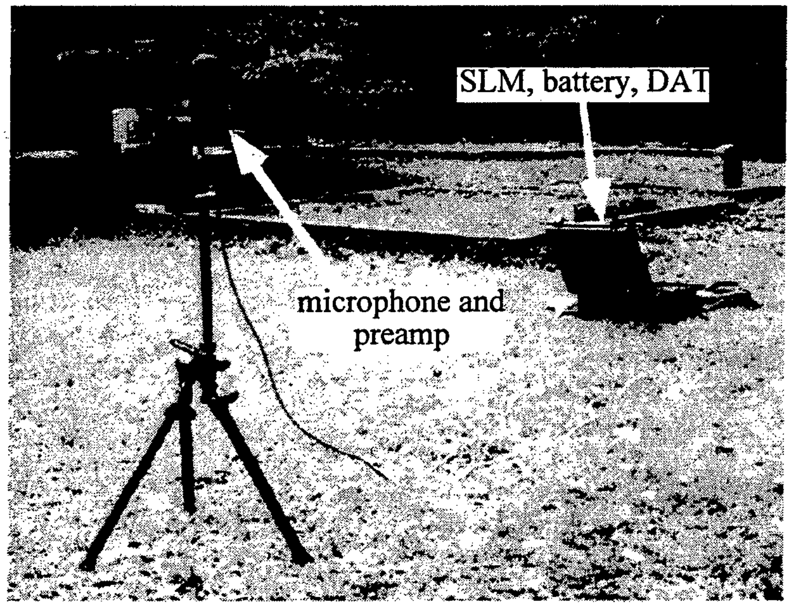


Figure 3.3 Picture of a sound level meter setup.

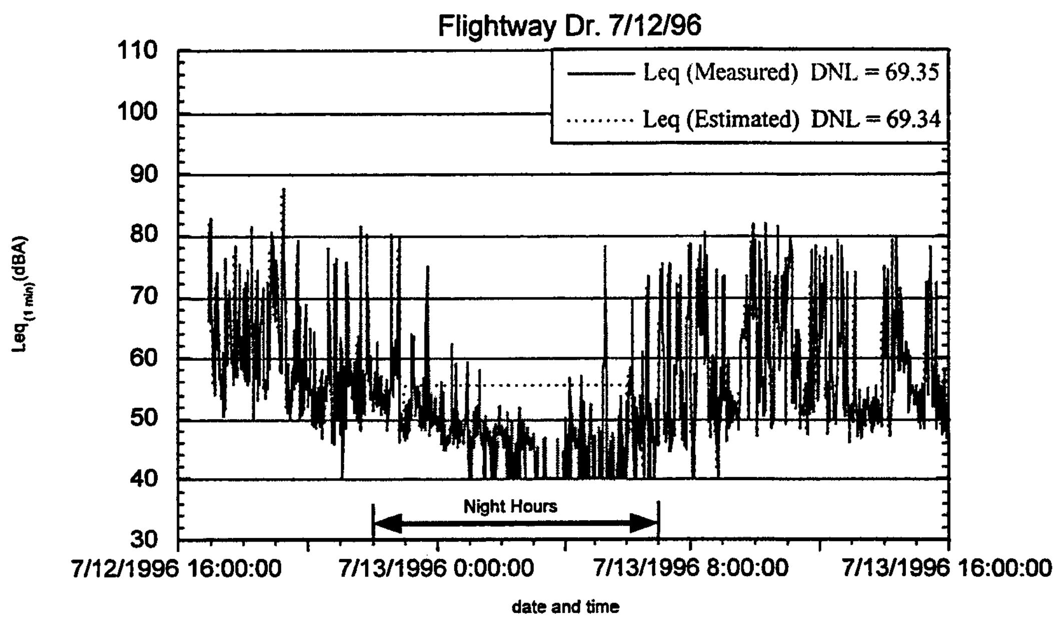


Figure 3.4 Verification of DNL reduction methodology.

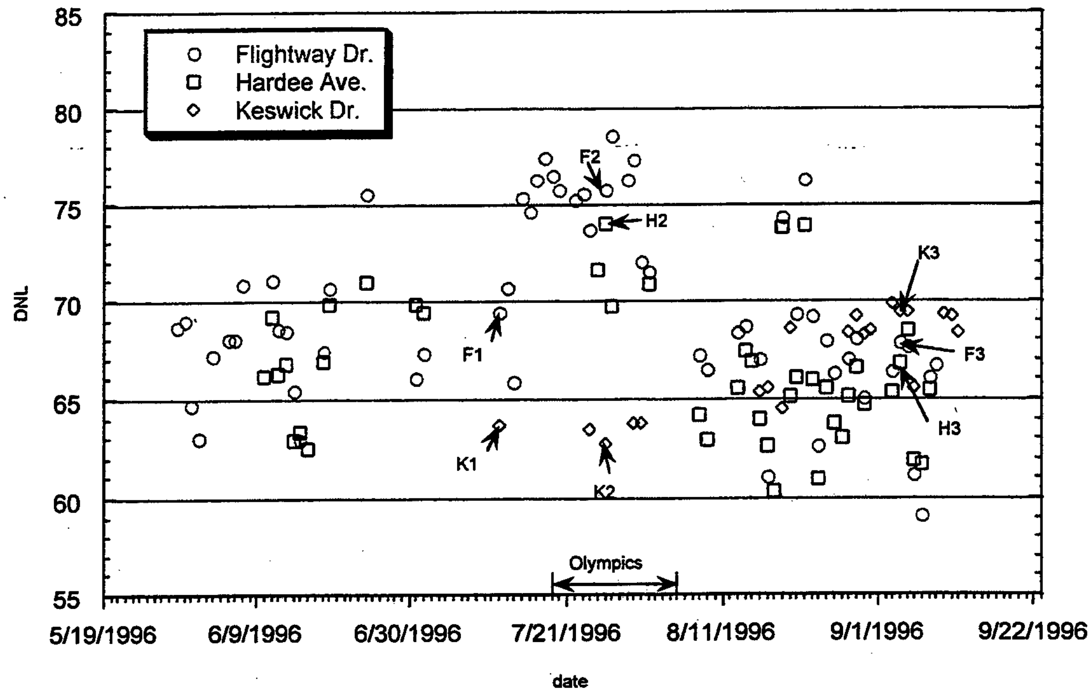
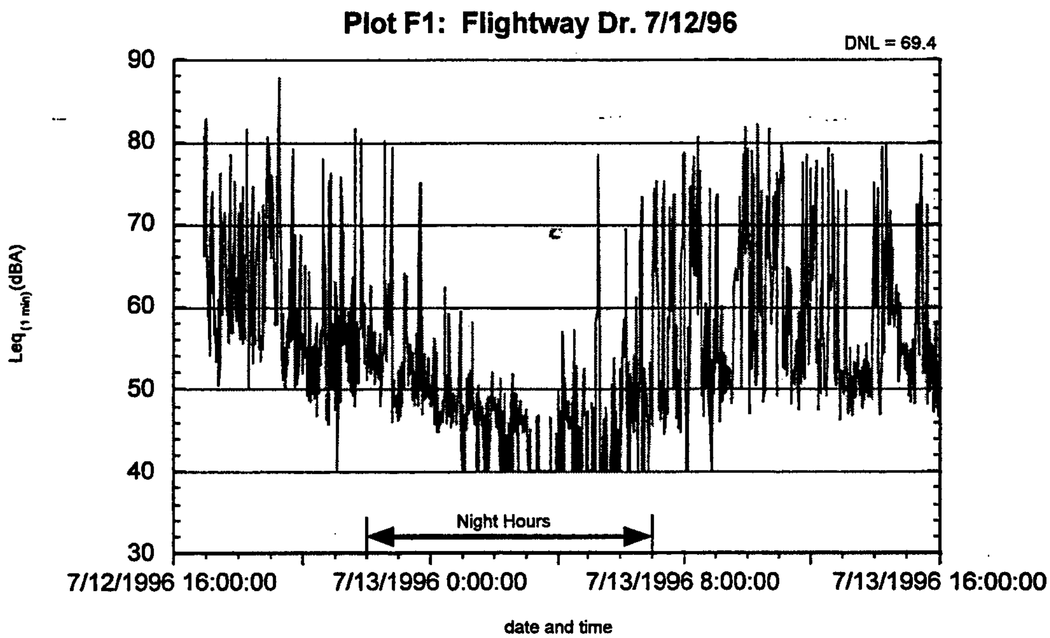
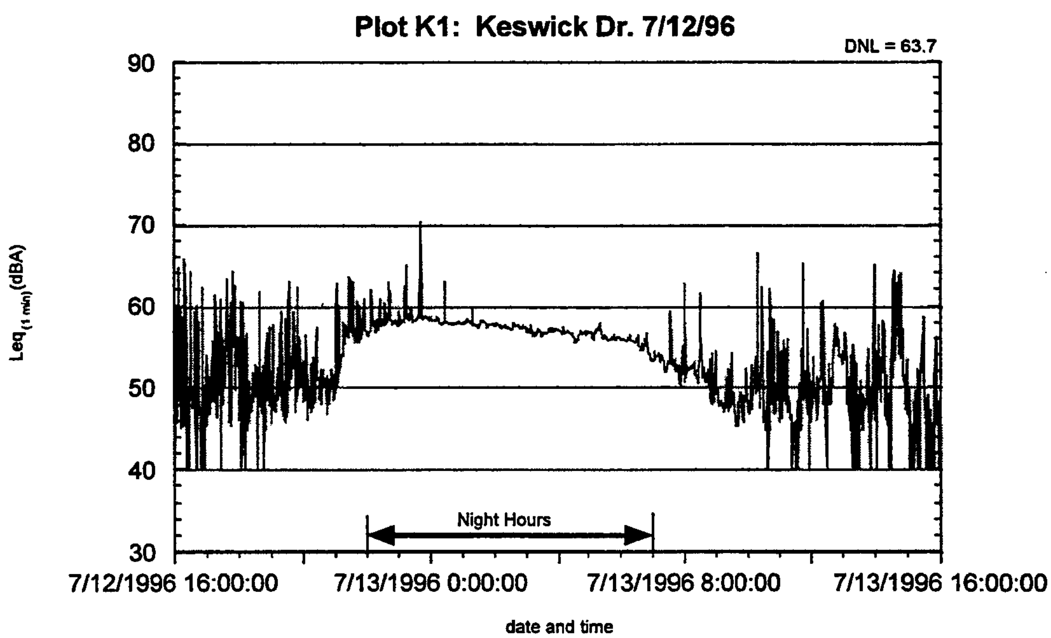


Figure 4.1 Variation of DNL at long-term monitored locations.



(a) Flightway Dr., location 52.



(b) Keswick Dr., location 59.

Figure 4.2 Variation of Leq on 12 July 1996.

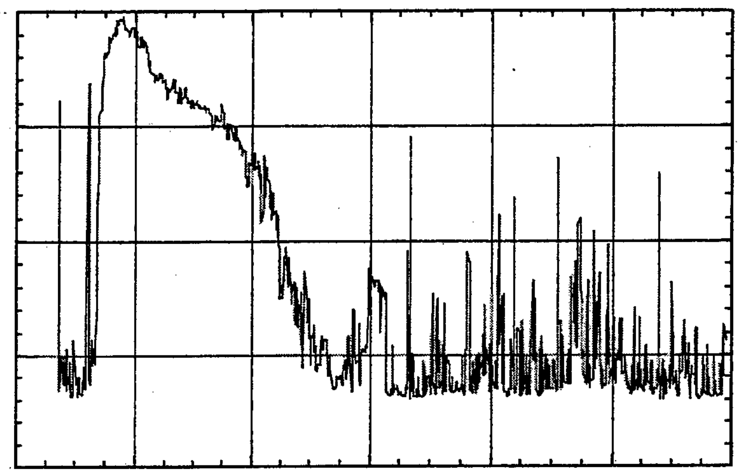
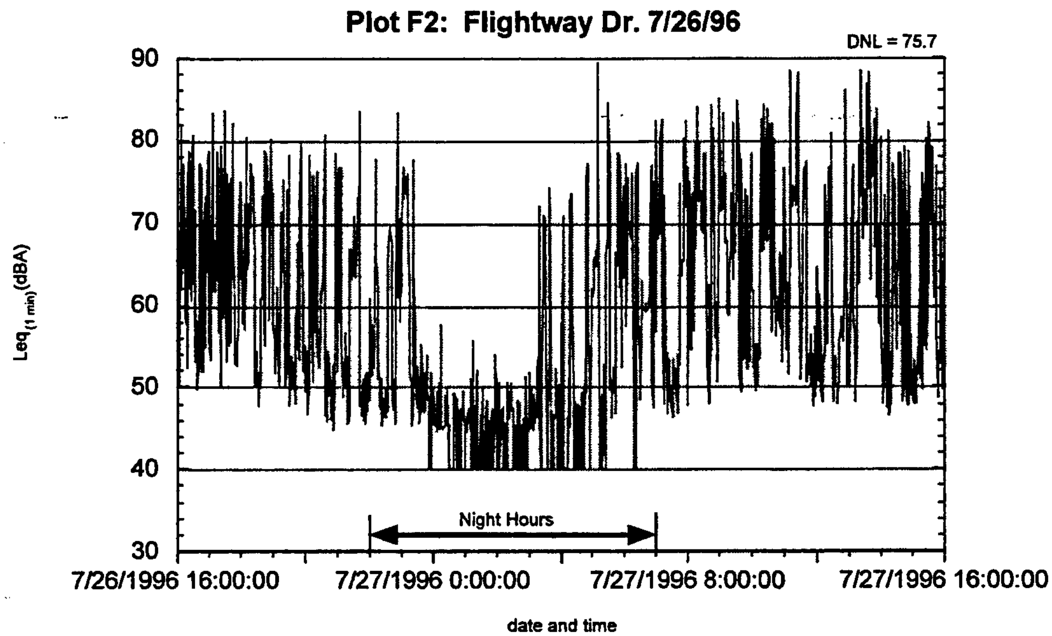
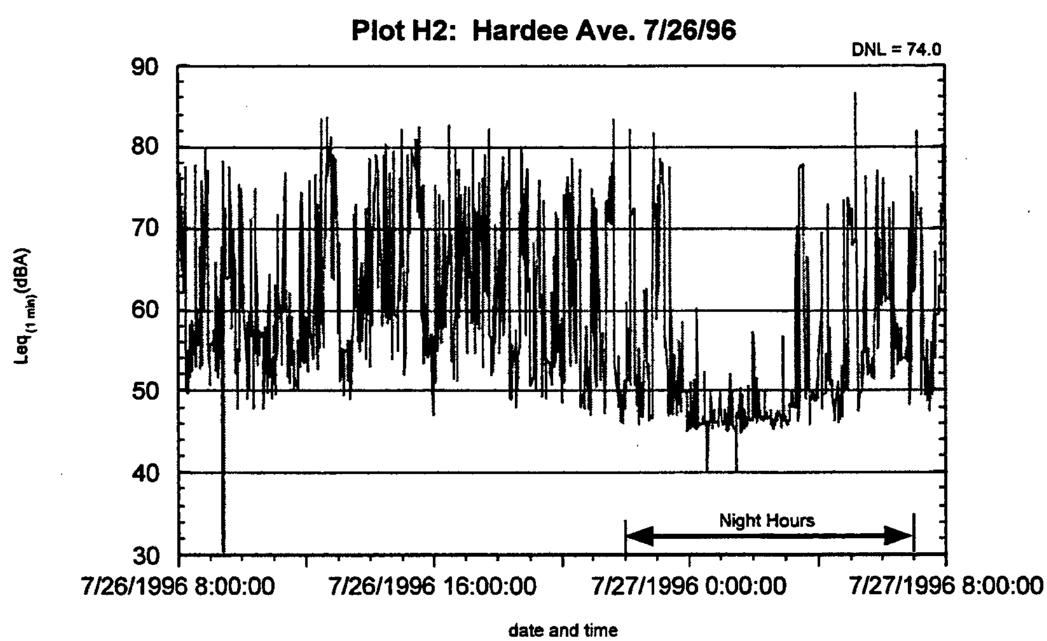


Figure 4.3 Variation of Leq at a mountain location showing effect of insect noise.

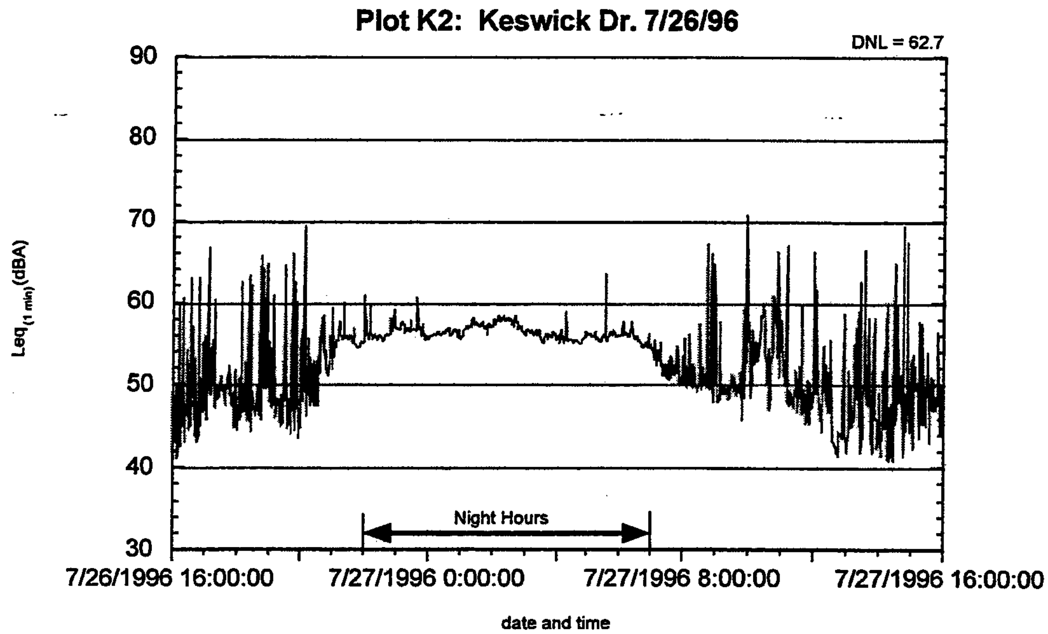


(a) Flightway Dr., location 52.



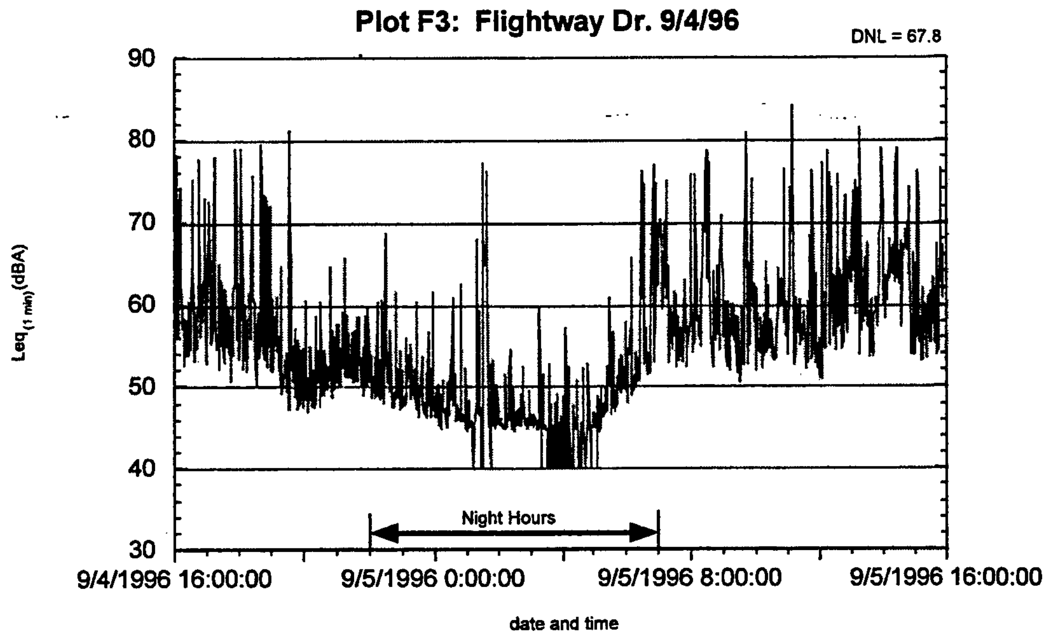
(b) Hardee Ave., location 53.

Figure 4.4 Variation of Leq on 26 July 1996.

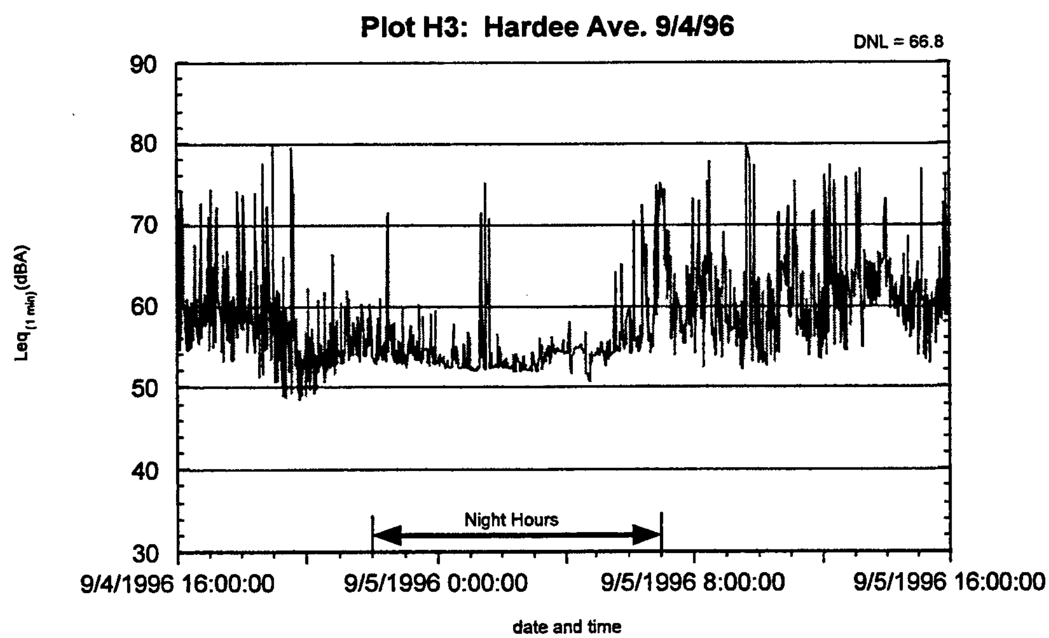


(c) Keswick Dr., location 59.

Figure 4.4 (continued)Variation of Leq on 26 July 1996.

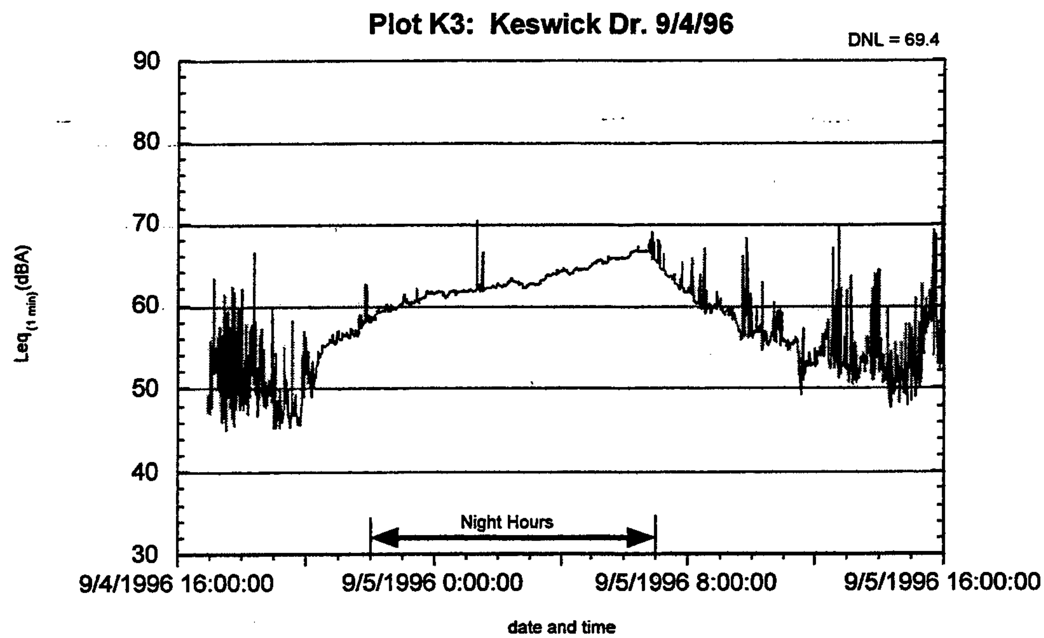


(a) Flightway Dr., location 52.



(b) Hardee Ave., location 53.

Figure 4.5 Variation of Leq on 4 September 1996.



(c) Keswick Dr., location 59.

Figure 4.5 (continued)Variation of Leq on 4 September 1996.

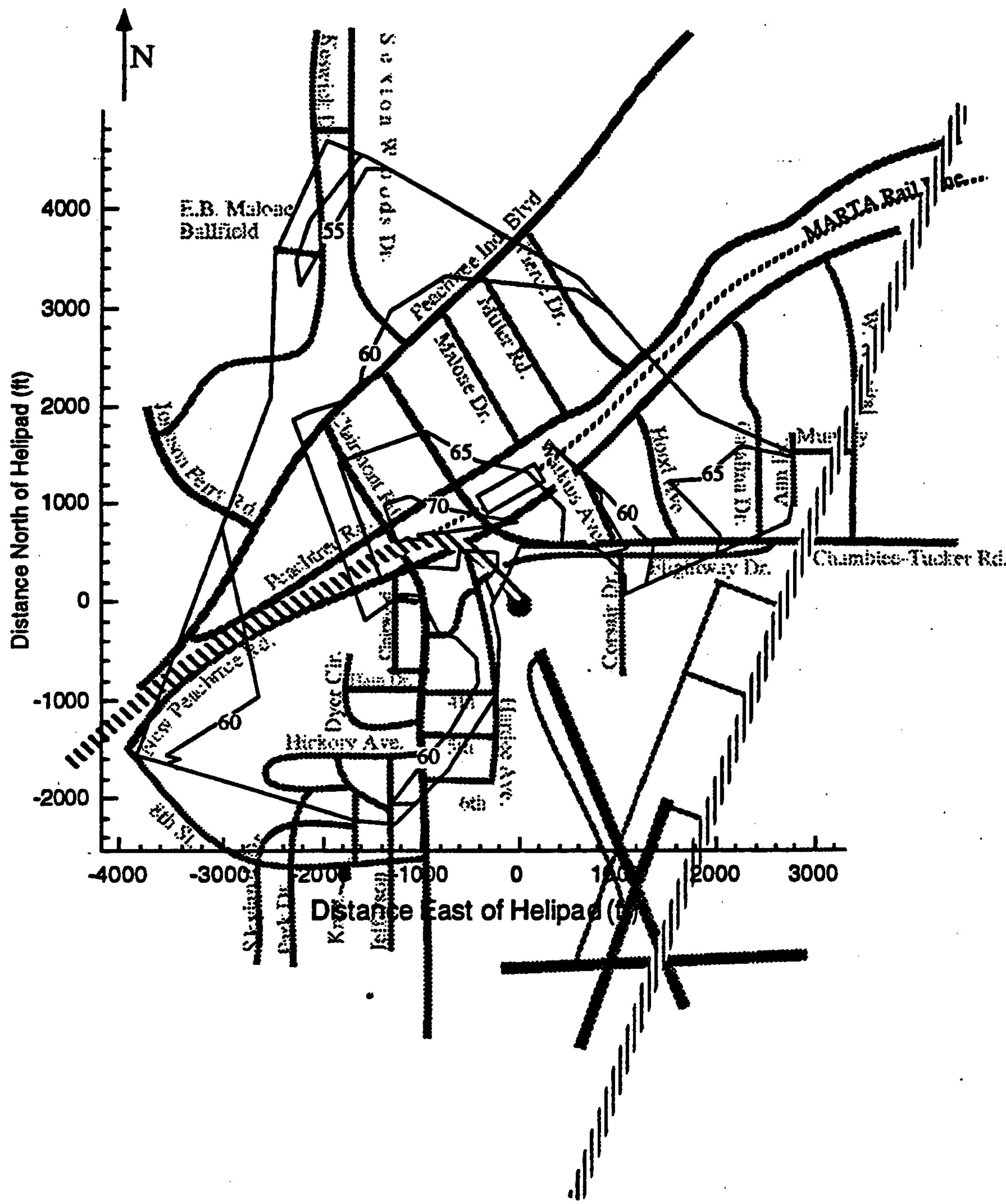


Figure 4.6 Pre-Olympic period DNL contours around the PDK helipad.

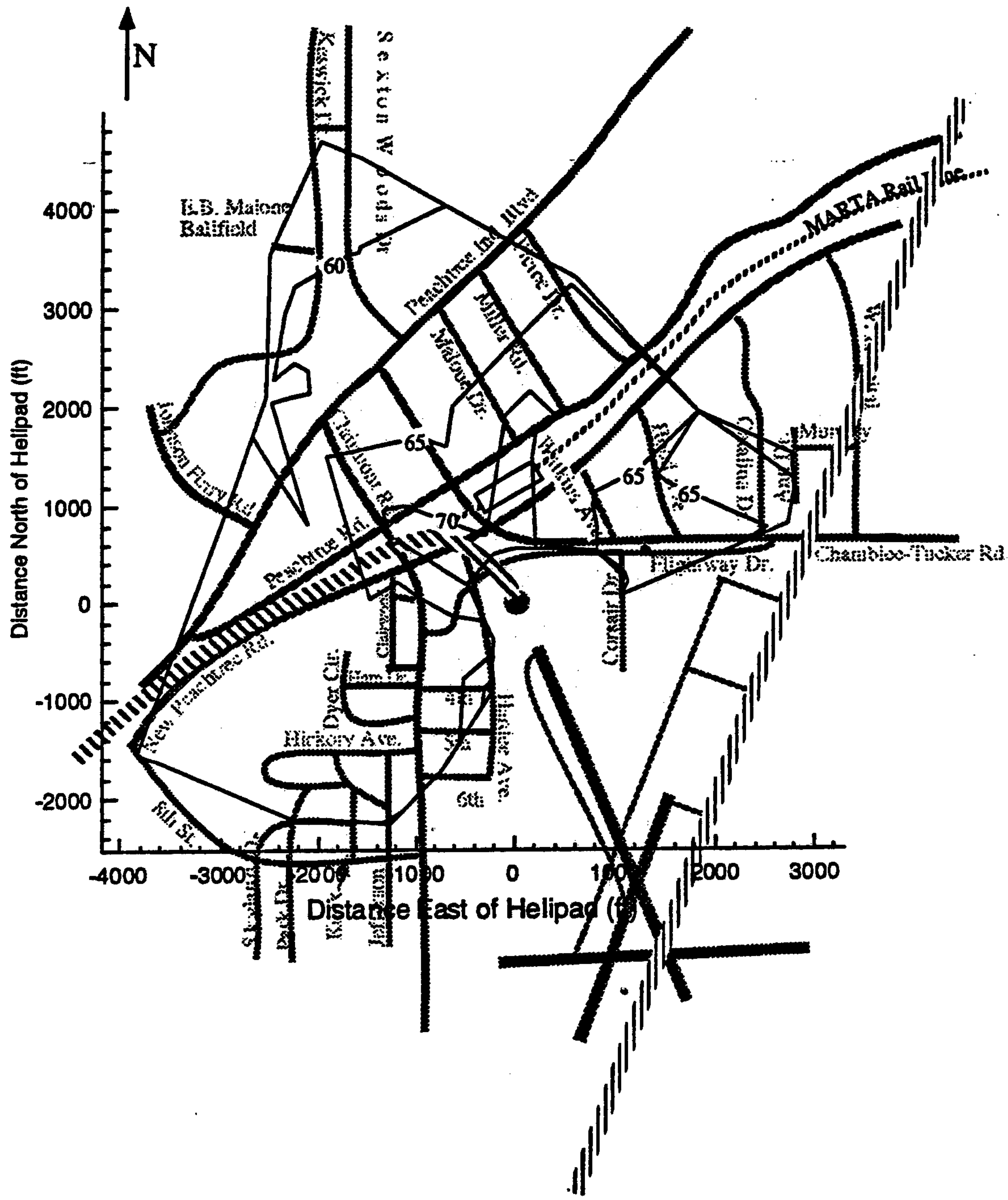


Figure 4.7 Olympic period DNL contours around the PDK helipad.

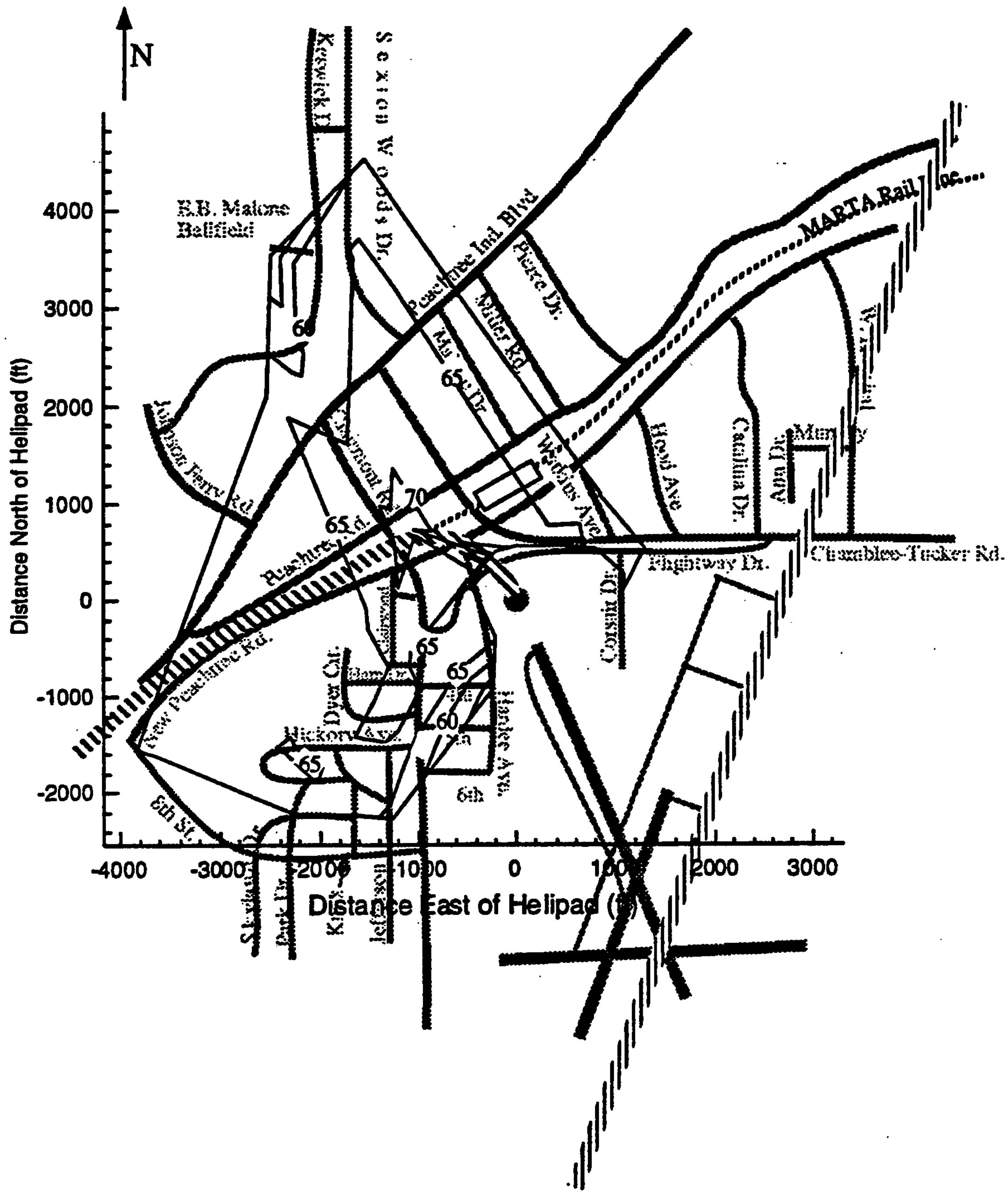


Figure 4.8 Post-Olympic period DNL contours around the PDK helipad

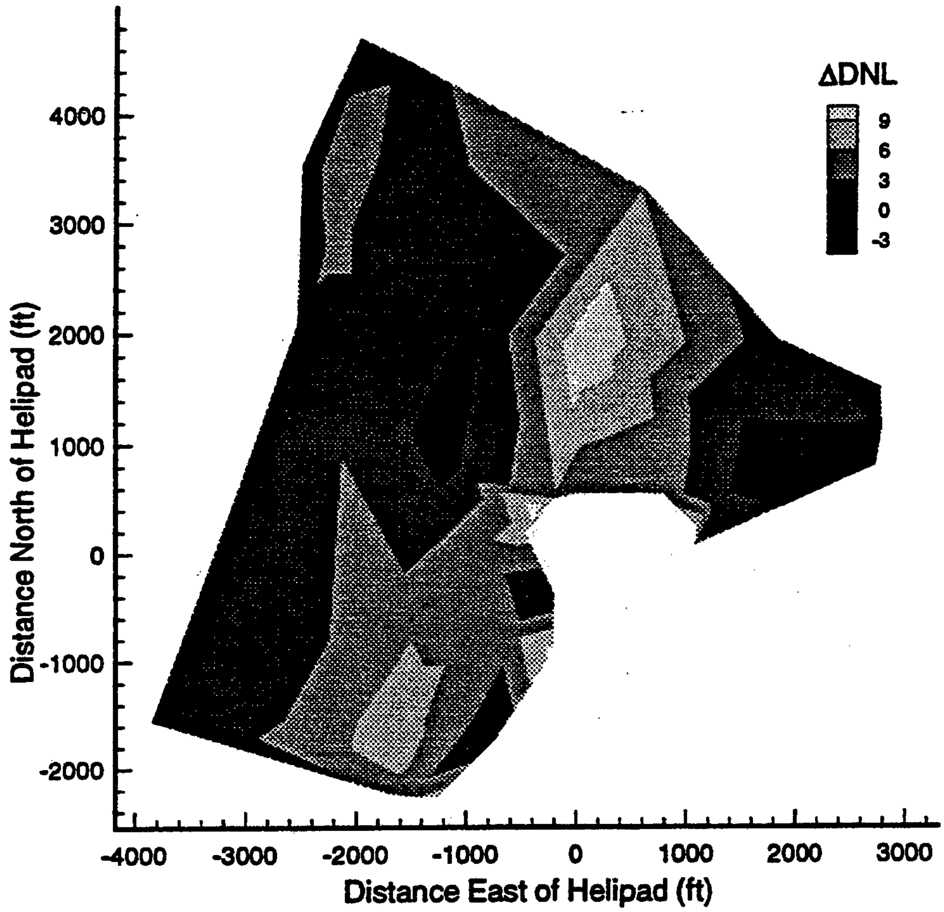


Figure 4.9 Contours of DNL change from pre-Olympic to Olympic measurements.

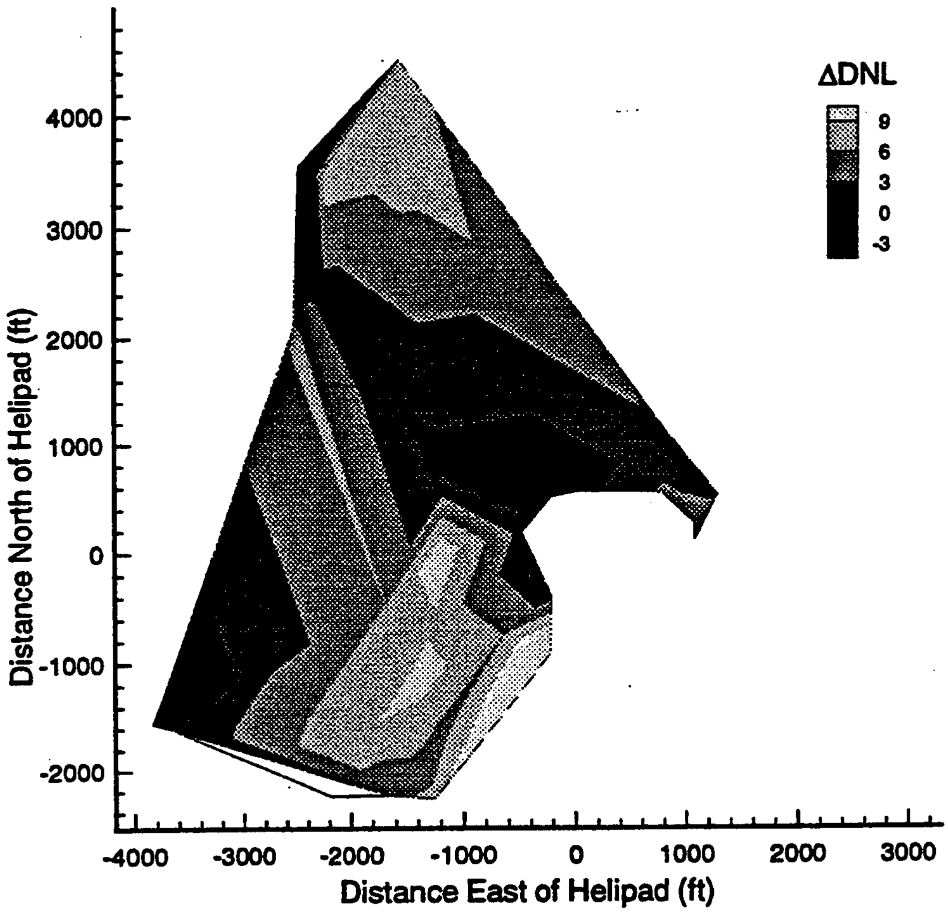


Figure 4.10 Contours of DNL change from pre-Olympic to post-Olympic measurements.

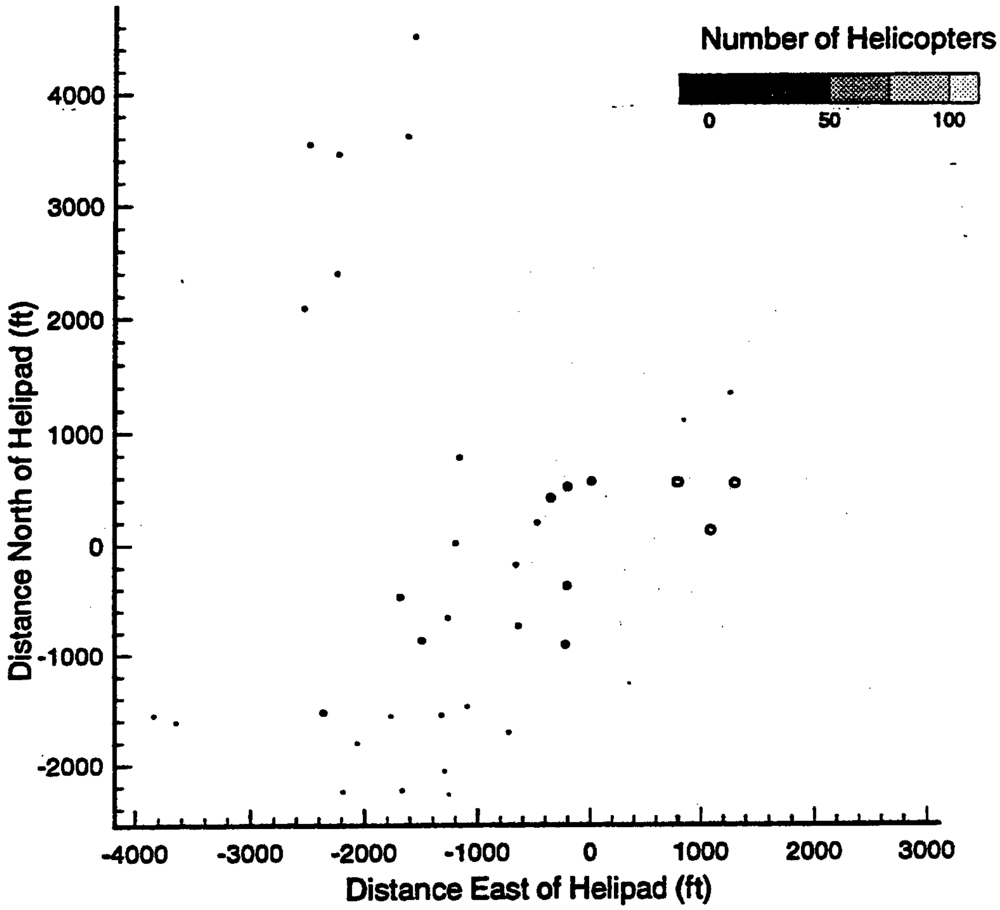


Figure 4.11 Typical helicopter activity levels around the PDK helipad.

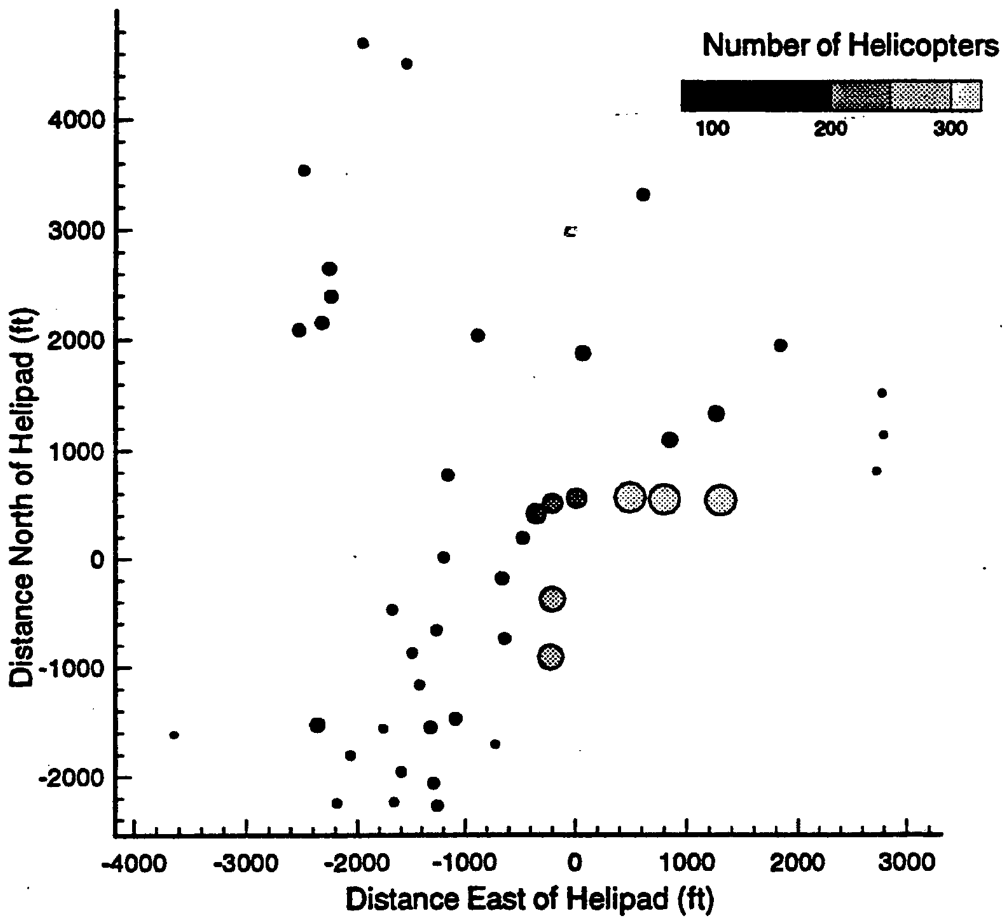
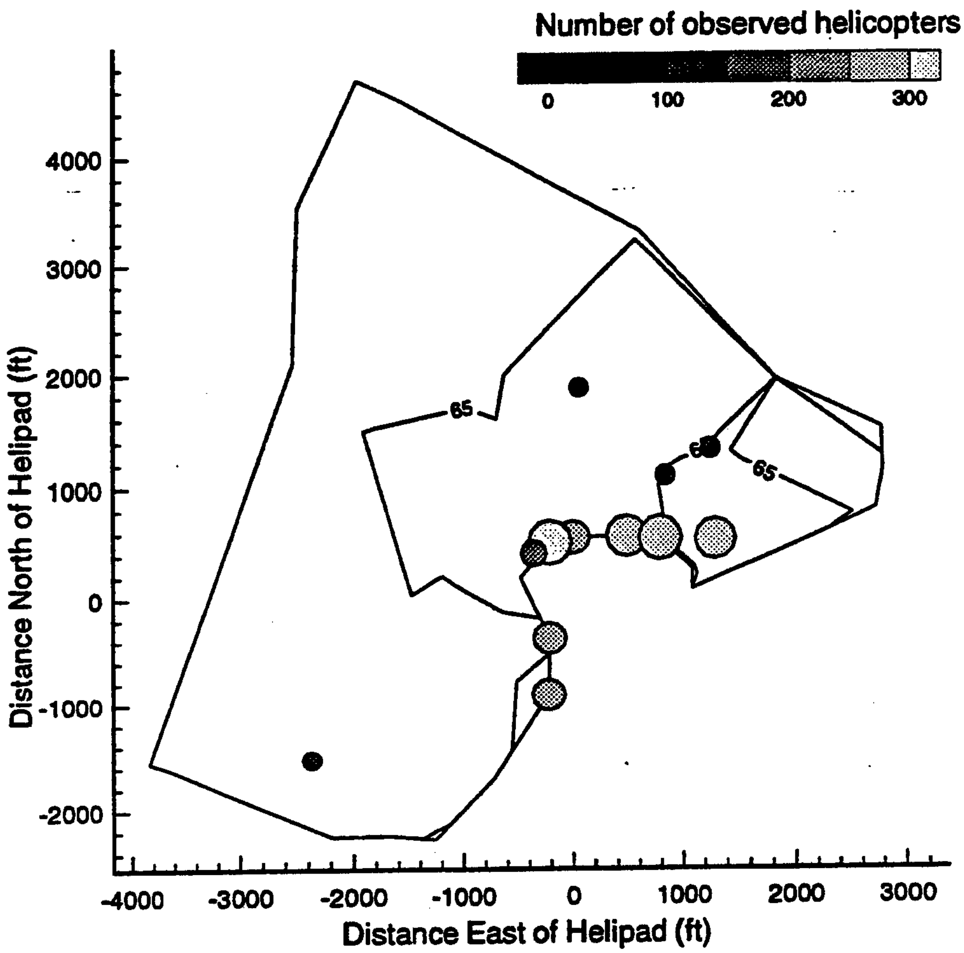
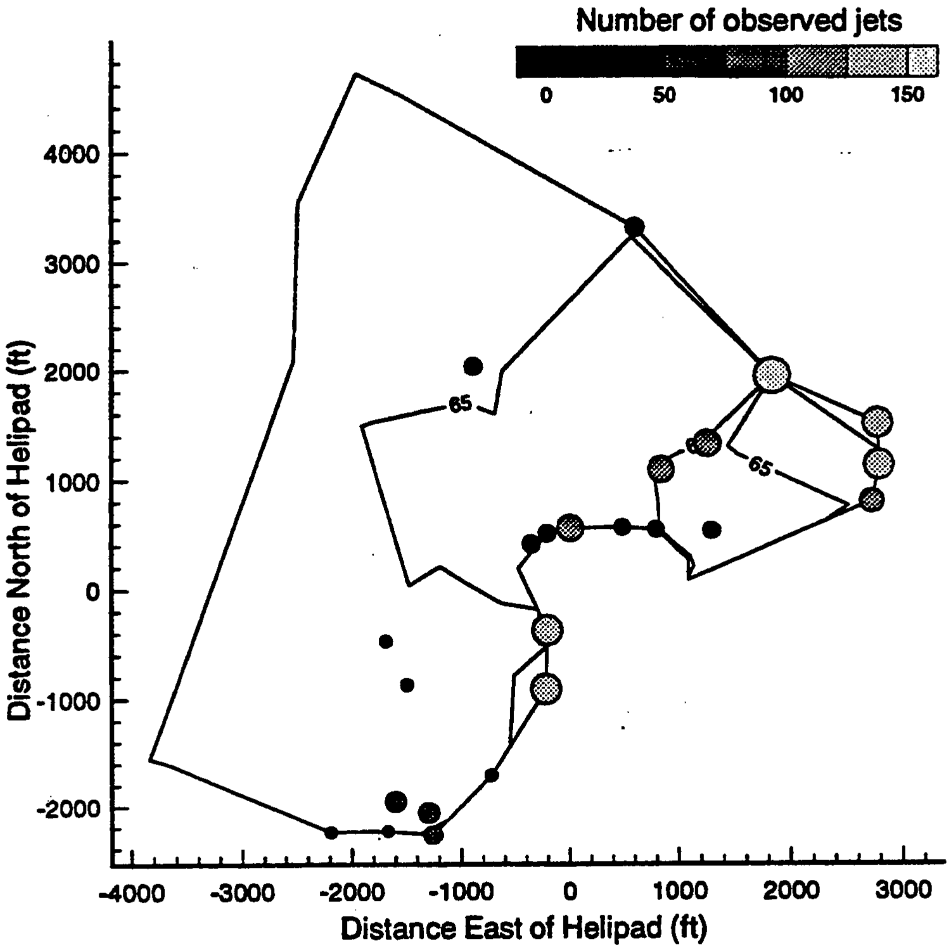


Figure 4.12 Helicopter activity levels during the Olympics.



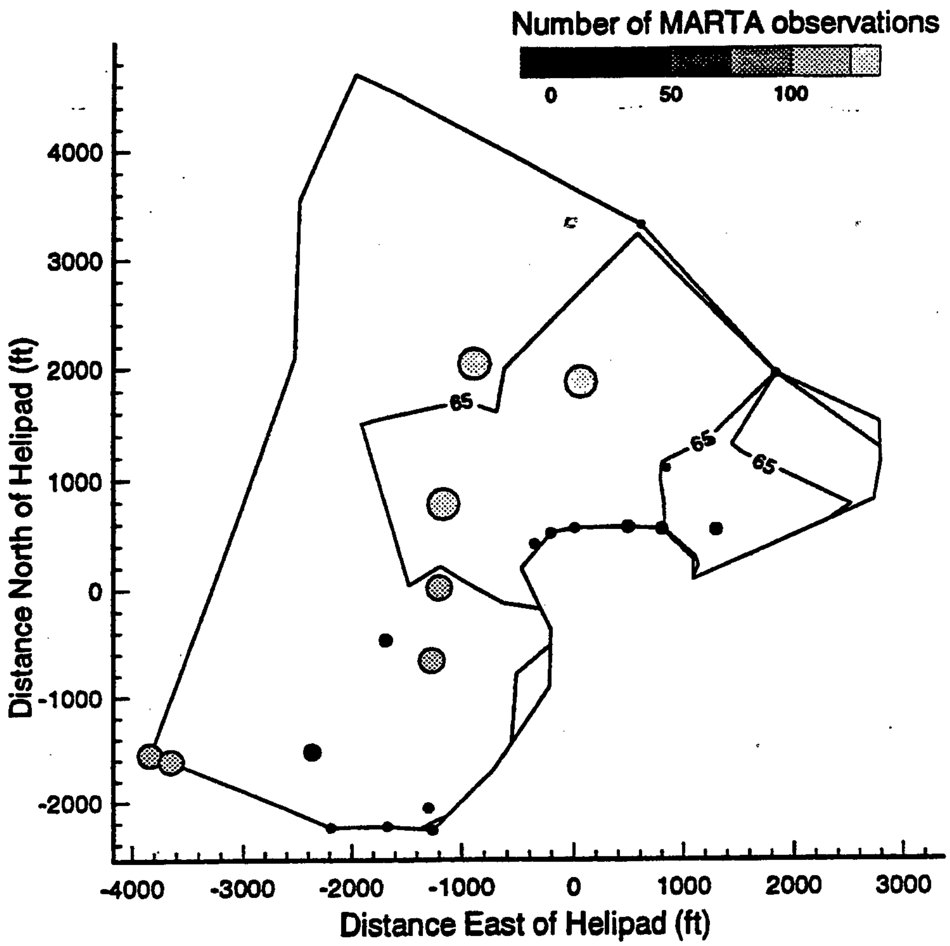
(a) Helicopter activity.

Figure 4.13 Transportation activity levels displayed with Olympic DNL contours.



(b) Business jet activity

Figure 4.13 (continued) Transportation activity levels displayed with Olympic DNL contours.



(c) MARTA rail activity.

Figure 4.13 (continued) Transportation activity levels displayed with Olympic DNL contours.

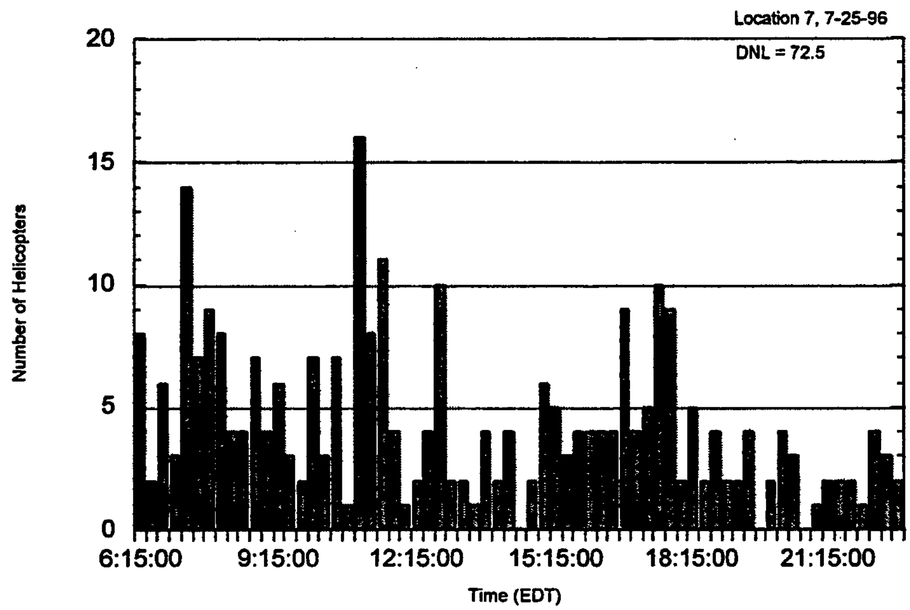


Figure 4.14 Time variation of helicopter activity monitored during the Olympics.

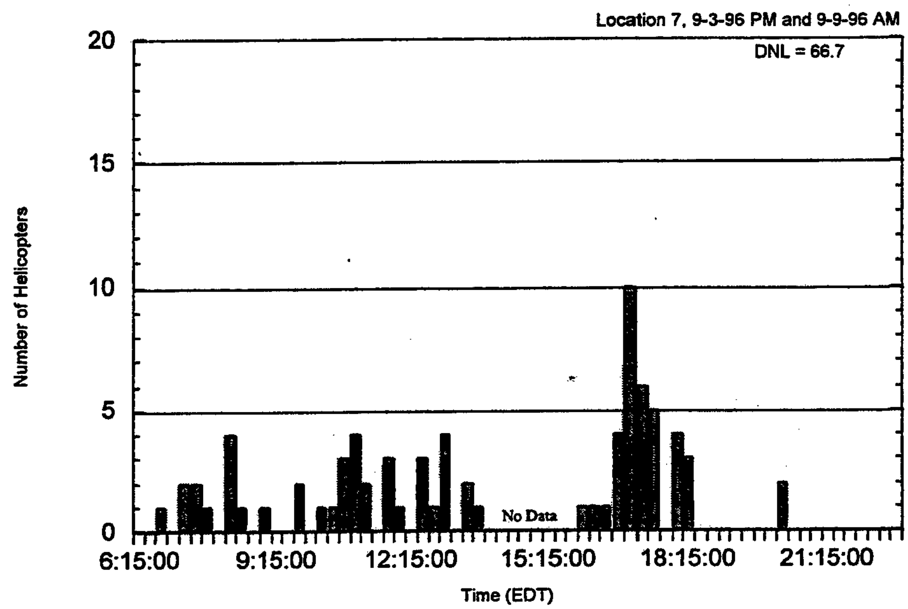


Figure 4.15 Time variation of helicopter activity monitored post-Olympics.